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Fujimoto et al.

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(45) Date of Patent: Feb. 2, 2016

(54) REFRIGERATION APPARATUS HAVING AN INTERCOOLER DISPOSED BETWEEN FIRST AND SECOND STAGES OF A COMPRESSION MECHANISM AND AN INTERCOOLER BYPASS TUBE TO BYPASS THE INTERCOOLER

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(22) PCT Filed: **Feb. 25, 2009**

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PCT Pub. Date: **Sep. 3, 2009**

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F25B 13/00 (2006.01)
F25B 1/10 (2006.01)
F25B 1/00 (2006.01)

(52) **U.S. Cl.**

CPC ... ***F25B 1/10*** (2013.01); *F25B 1/00* (2013.01); *F25B 13/00* (2013.01);

(Continued)

(58) **Field of Classification Search**

CPC F25B 13/00; F25B 1/00; F25B 41/00; F25B 2400/04

USPC 62/324.6, 510, 512, 513, 498, 196.2, 62/324.2

See application file for complete search history.

(56) **References Cited**

U.S. PATENT DOCUMENTS

2004/0040339 A1 3/2004 Matsumoto et al.
2004/0089015 A1* 5/2004 Knight et al. 62/324.1

(Continued)

FOREIGN PATENT DOCUMENTS

DE 103 13 850 A1 10/2004
JP 2004-116957 A 4/2004

(Continued)

OTHER PUBLICATIONS

International Preliminary Report of corresponding PCT Application No. PCT/JP2009/053318.

(Continued)

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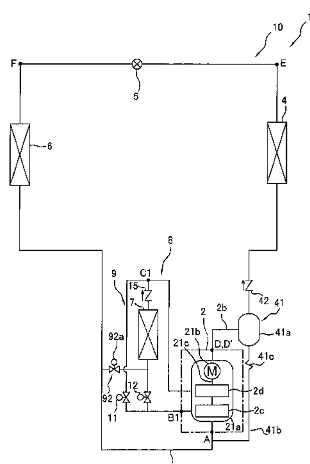
(74) *Attorney, Agent, or Firm* — Global IP Counselors

(57) **ABSTRACT**

A refrigeration apparatus includes a compression mechanism, a heat source-side heat exchanger, a usage-side heat exchanger, an intercooler, an intercooler bypass tube and an intake return tube. The compression mechanism has a plurality of compression elements configured so that refrigerant discharged from a first-stage compression element is sequentially compressed by a second-stage compression element. The intercooler is connected to an intermediate refrigerant tube configured to draw refrigerant discharged from the first-stage compression element into the second-stage compression element to cool the refrigerant discharged from the first-stage compression element and drawn into the second-stage compression element. The intercooler bypass tube is connected to the intermediate refrigerant tube so as to bypass the intercooler. The intake return tube is configured to connect the intercooler and an intake side of the compression mechanism when the refrigerant discharged from the first-stage compression element is drawn into the second-stage compression element through the intercooler bypass tube.

4 Claims, 17 Drawing Sheets



(52) **U.S. Cl.**
CPC .. *F25B 2309/061* (2013.01); *F25B 2313/0272* (2013.01); *F25B 2313/02741* (2013.01); *F25B 2400/04* (2013.01); *F25B 2400/072* (2013.01); *F25B 2400/075* (2013.01); *F25B 2400/13* (2013.01)

(56) **References Cited**

U.S. PATENT DOCUMENTS

2005/0072173	A1	4/2005	Yamasaki et al.
2005/0144964	A1	7/2005	Matsumoto et al.
2005/0144972	A1	7/2005	Matsumoto et al.
2005/0144973	A1	7/2005	Matsumoto et al.
2005/0144977	A1	7/2005	Matsumoto et al.
2005/0172661	A1	8/2005	Matsumoto et al.
2005/0172662	A1	8/2005	Matsumoto et al.
2005/0183447	A1	8/2005	Matsumoto et al.
2009/0044564	A1	2/2009	Okamoto

FOREIGN PATENT DOCUMENTS

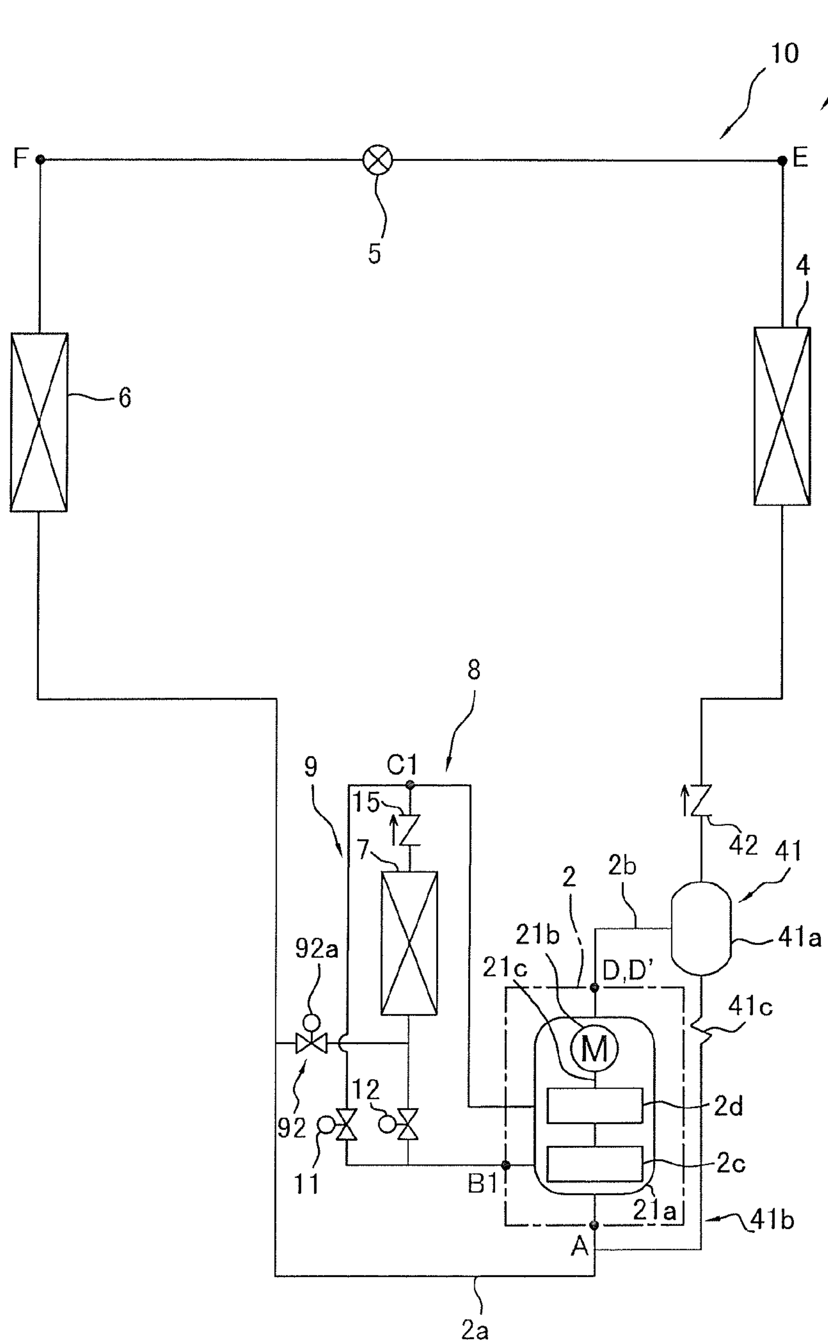
JP	2004-301453	A		10/2004	
JP	2005-003239	A		1/2005	
JP	2007-115096	A		5/2007	
JP	2007-183044		*	7/2007	.... F25B 1/10
JP	2007-183044	A	*	7/2007	
JP	2007-183044	A		7/2007	
JP	2007-232263	A		9/2007	

OTHER PUBLICATIONS

International Search Report of corresponding PCT Application No. PCT/JP2009/053318.

The extended European search report for the corresponding European application No. 09715946.1, issued on Nov. 2, 2015.

* cited by examiner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10
F
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5
4
6
8
9
C1
15
7
42
41
2b
2
21b
41a
21c
D,D'
92a
41c
M
92
12
2d
2c
11
B1
21a
41b
A
2a

FIG. 1

FIG. 2

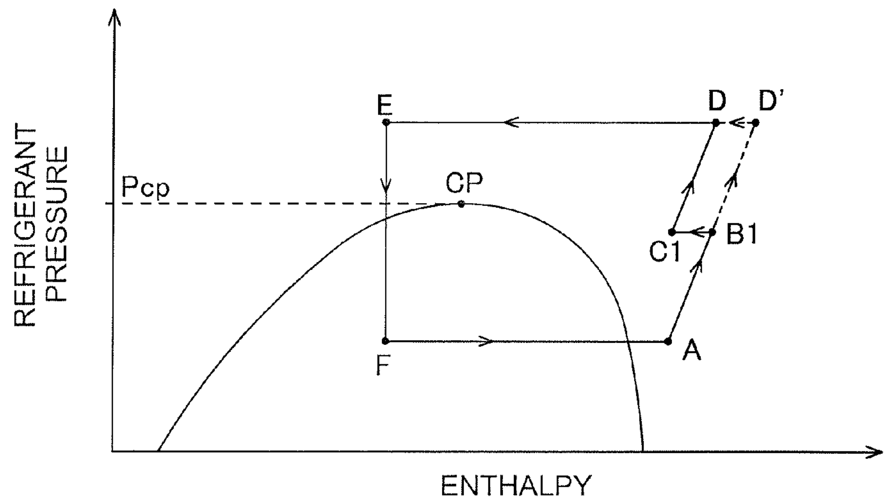
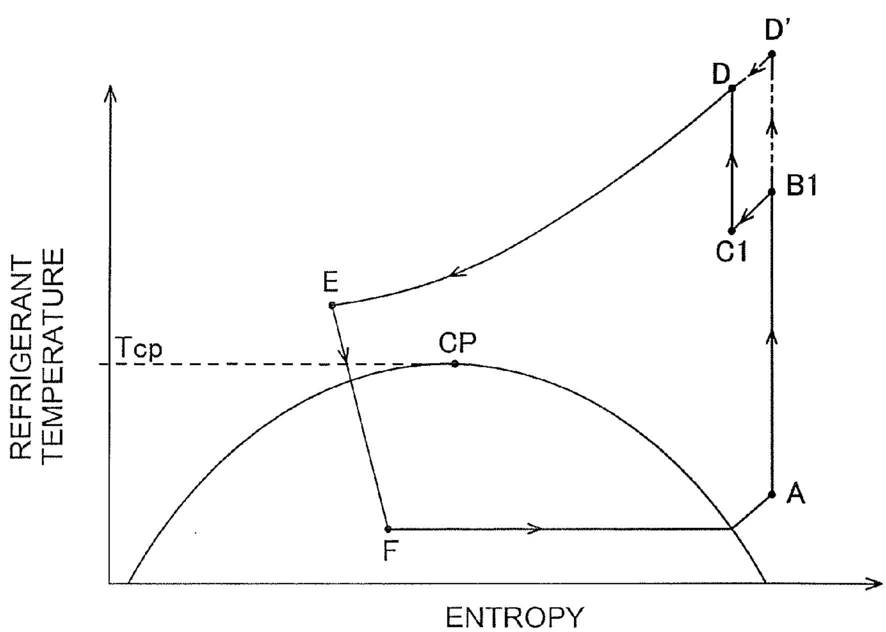

REFRIGERANT PRESSURE
ENTHALPY
Pcp
CP
E
D
D'
B1
C1
A
F

FIG. 3


REFRIGERANT TEMPERATURE
ENTROPY
Tcp
CP
D'
D
B1
C1
E
A
F

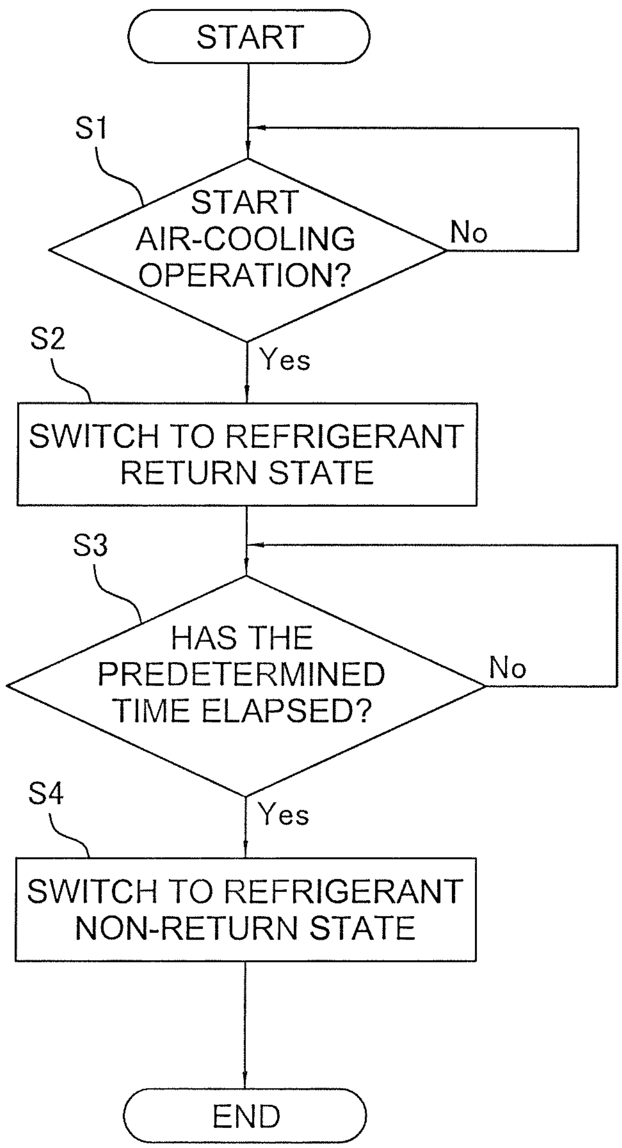

START
S1
START AIR-COOLING OPERATION?
No
Yes
S2
SWITCH TO REFRIGERANT RETURN STATE
S3
HAS THE PREDETERMINED TIME ELAPSED?
No
Yes
S4
SWITCH TO REFRIGERANT NON-RETURN STATE
END

FIG. 4

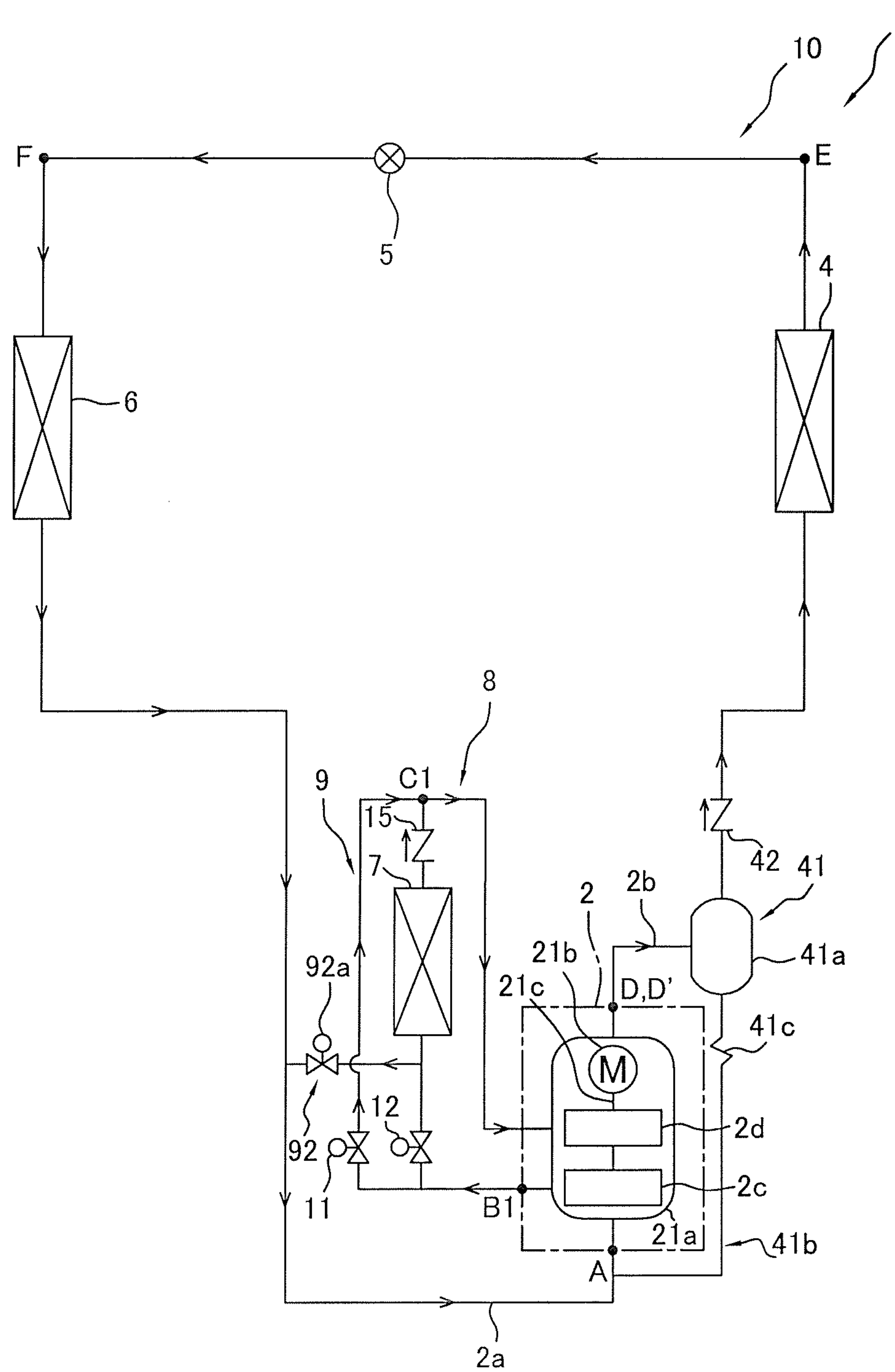
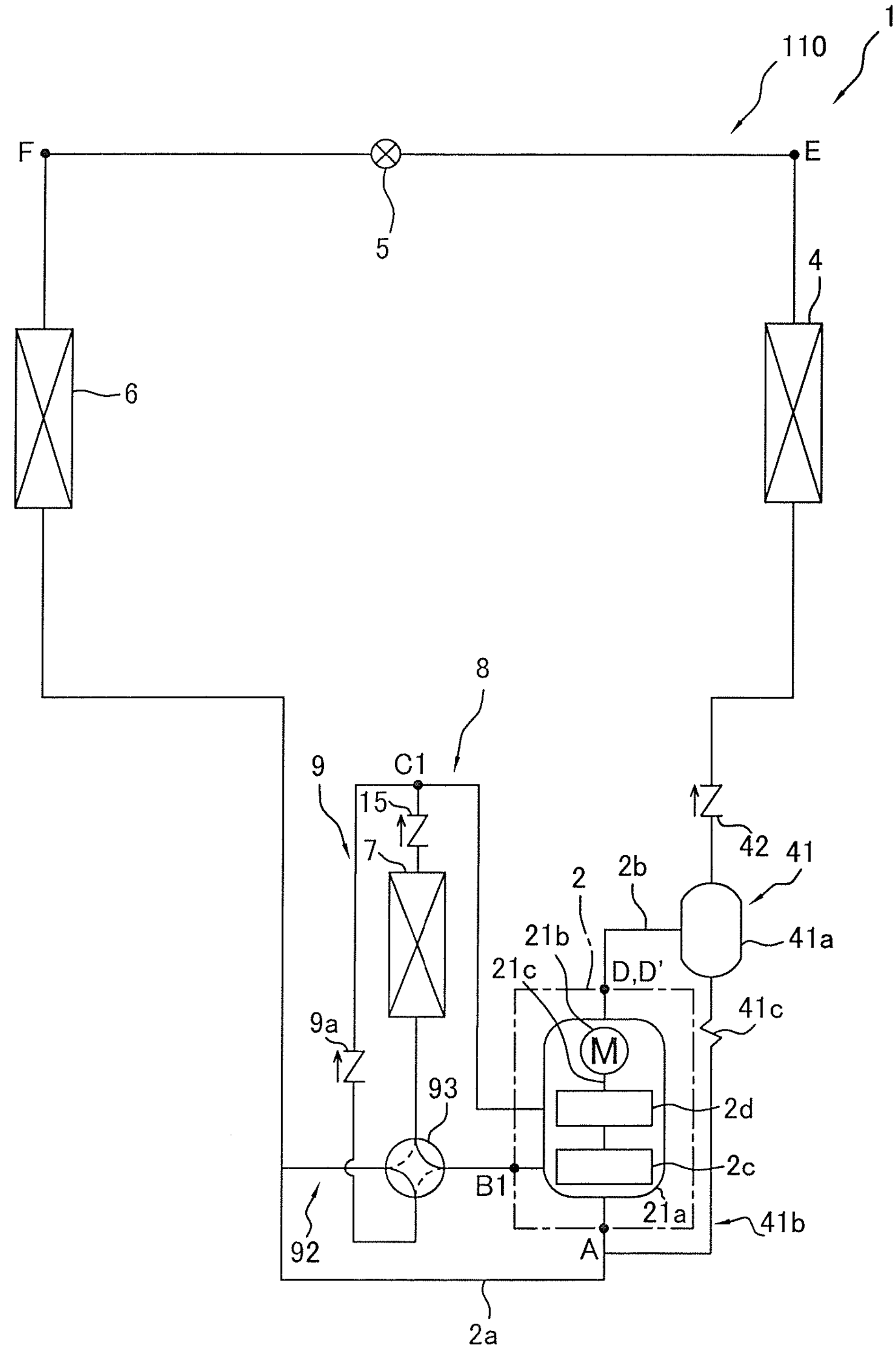

1
10
F
E
5
4
6
8
C1
9
15
7
42
41
2
2b
21b
92a
D,D'
41a
21c
M
41c
12
2d
92
11
2c
B1
21a
41b
A
2a

FIG. 5


110
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F
E
5
4
6
8
9
C1
15
7
42
41
2
2b
21b
41a
21c
D,D'
41c
M
9a
93
2d
2c
B1
21a
41b
92
A
2a

FIG. 6

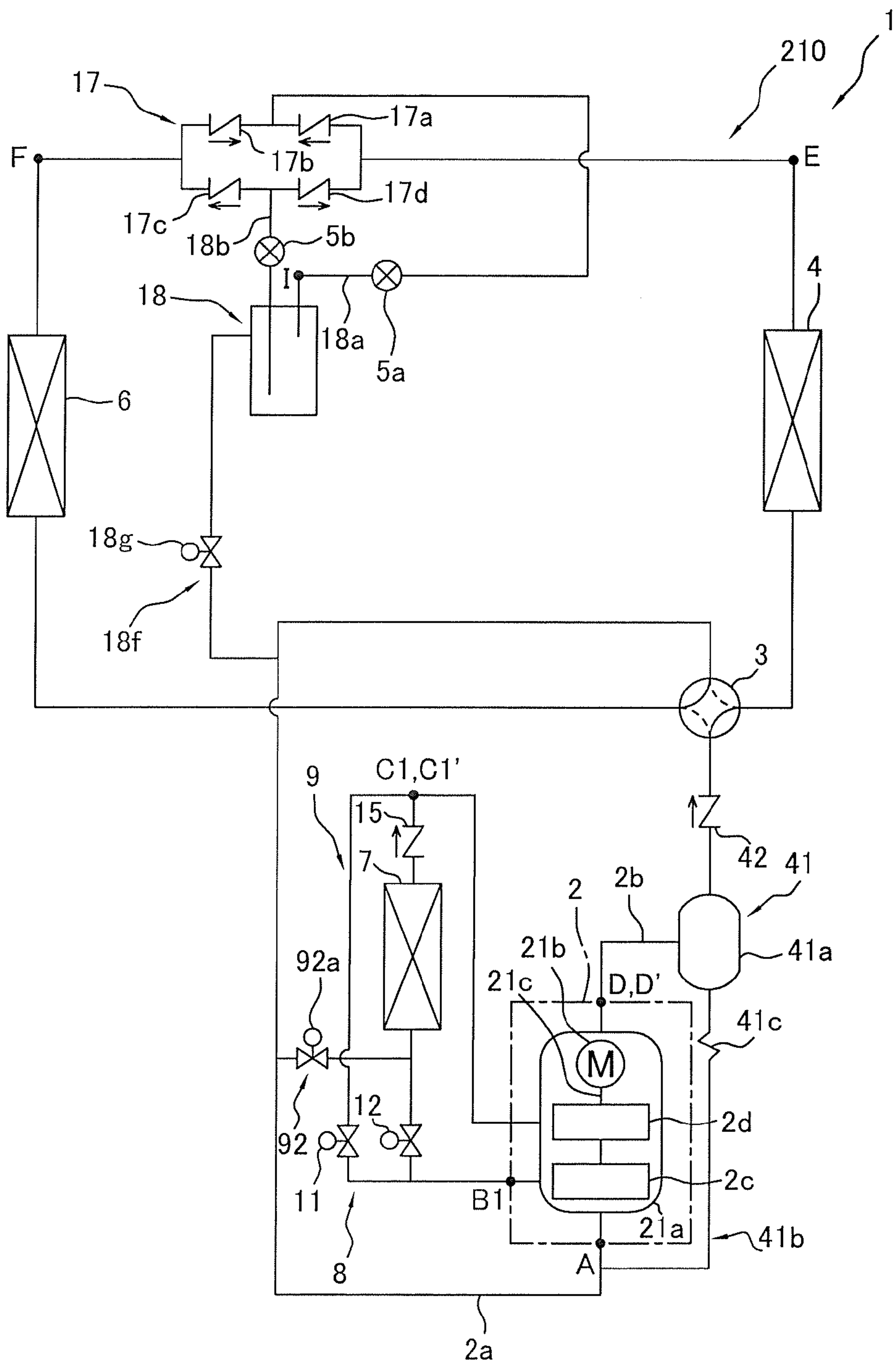

1
210
17
17a
17b
17c
17d
F
E
18b
5b
I
5a
18
18a
4
6
18g
18f
3
9
C1,C1'
15
7
42
41
2
2b
41a
92a
21b
21c
D,D'
41c
M
2d
12
92
11
2c
B1
21a
41b
A
8
2a

FIG. 7

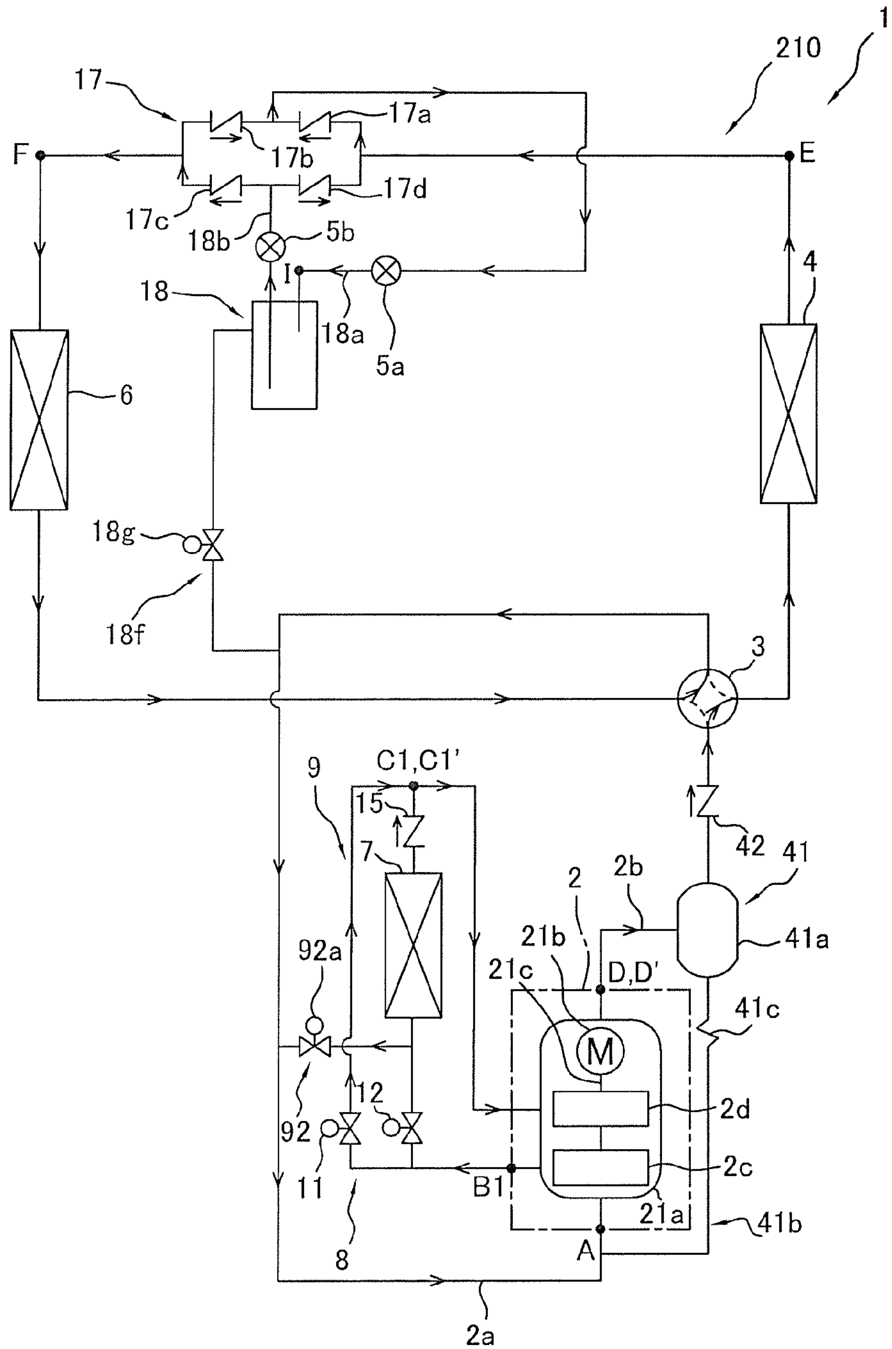

1
210
17
17a
17b
17c
17d
F
E
18b
5b
I
18
18a
5a
6
4
18g
18f
3
9
C1,C1'
15
7
42
41
2
2b
41a
21b
21c
D,D'
92a
41c
M
12
2d
92
11
2c
B1
21a
41b
8
A
2a

FIG. 8

FIG. 9

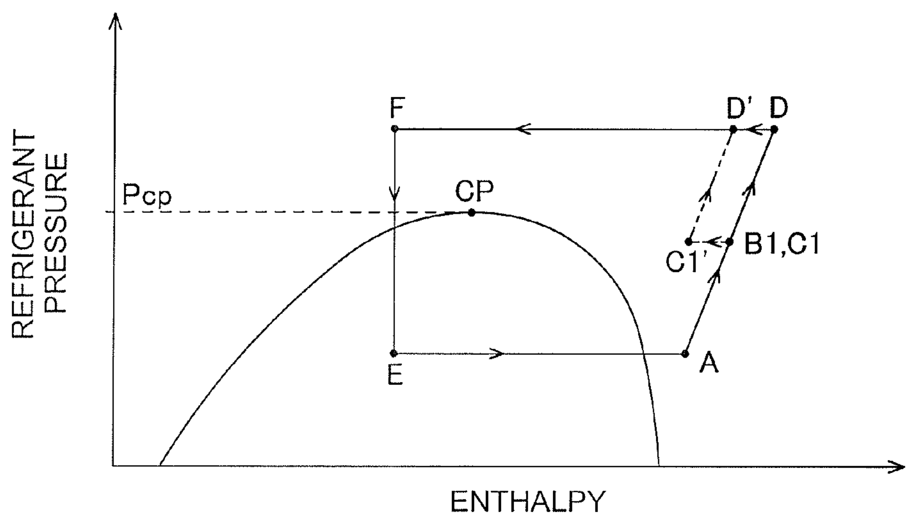
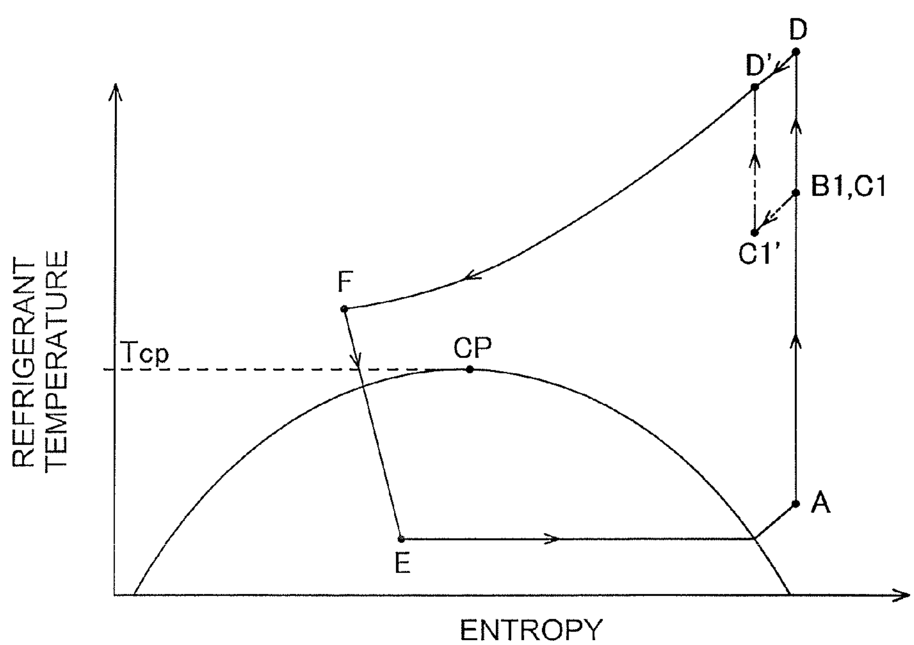

REFRIGERANT PRESSURE
Pcp
F
CP
D' D
B1,C1
C1'
E
A
ENTHALPY

FIG. 10


D
D'
B1,C1
C1'
F
REFRIGERANT TEMPERATURE
Tcp
CP
A
E
ENTROPY

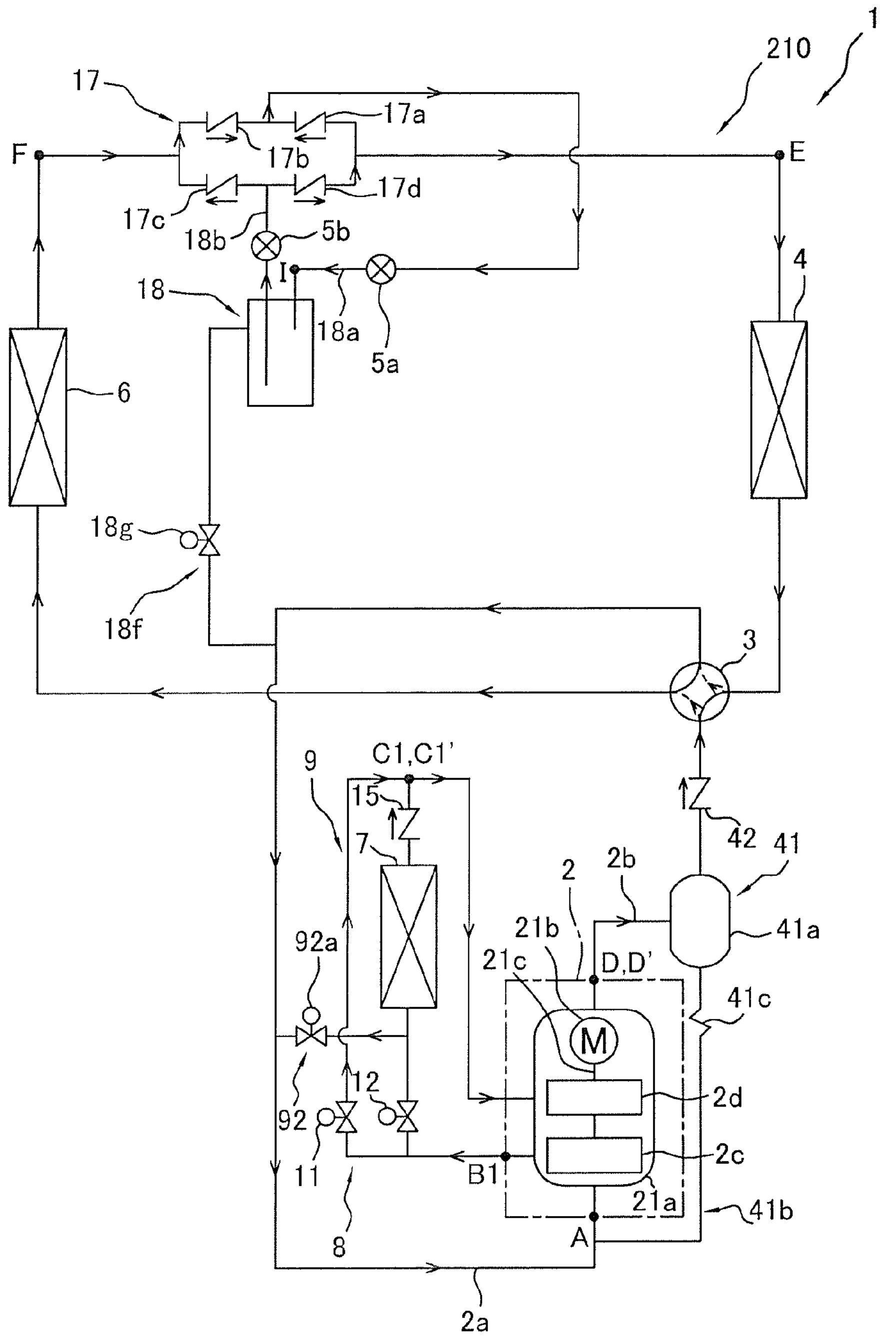

1
210
17
17a
17b
17c
17d
F
E
18b
5b
I
18
18a
5a
4
6
18g
18f
3
9
C1,C1'
15
7
42
41
2b
2
21b
21c
D,D'
41a
92a
41c
92
12
11
2d
2c
B1
21a
8
A
41b
2a

FIG. 11

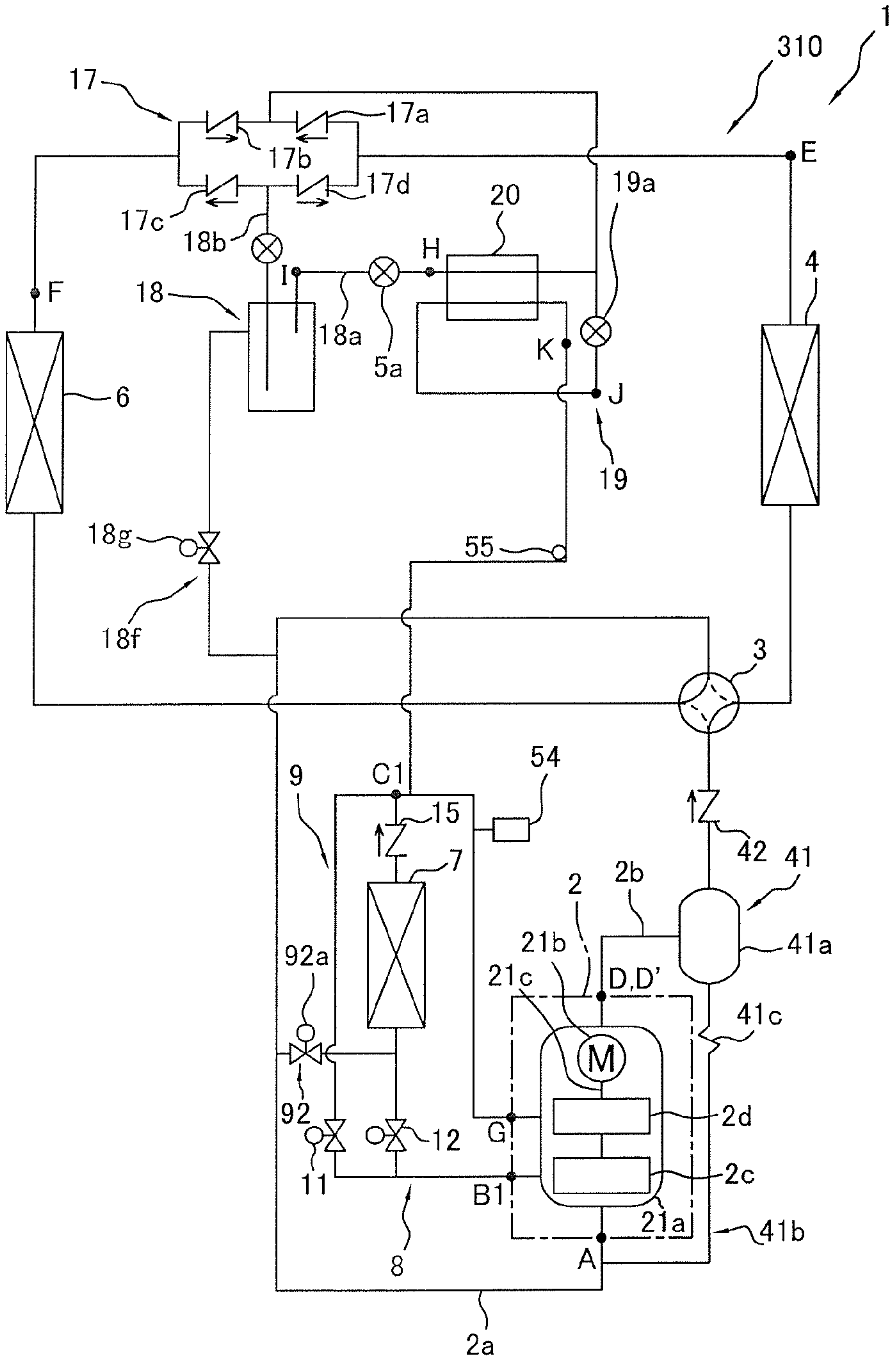

1
310
17
17a
17b
17c
17d
E
20
19a
18b
H
I
F
18
18a
5a
4
K
J
6
19
18g
55
18f
3
9
C1
54
15
7
42
41
2b
2
21b
41a
92a
21c
D,D'
41c
M
92
2d
G
12
11
B1
2c
21a
41b
A
8
2a

FIG. 12

FIG. 13

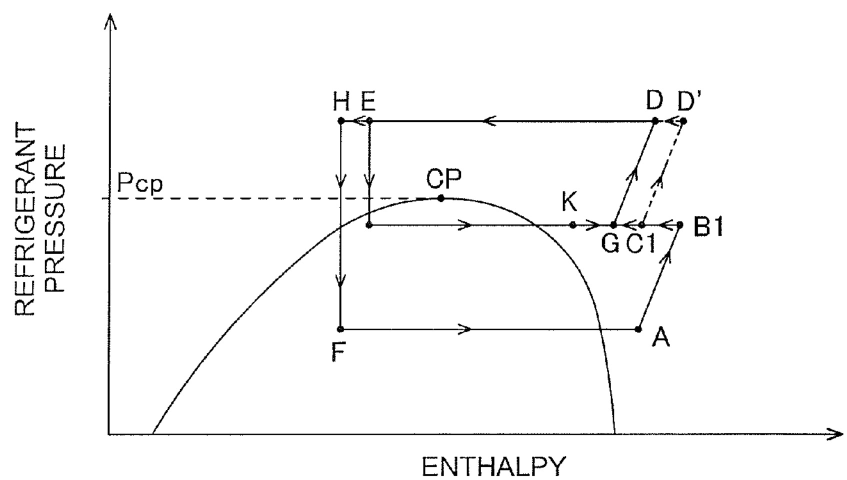

REFRIGERANT PRESSURE
Pcp
H
E
D
D'
CP
K
G
C1
B1
F
A
ENTHALPY

FIG. 14

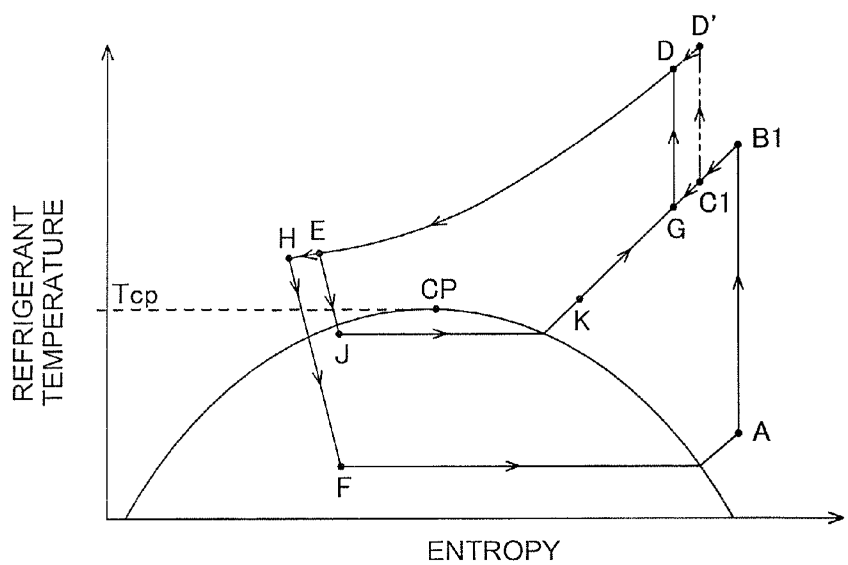
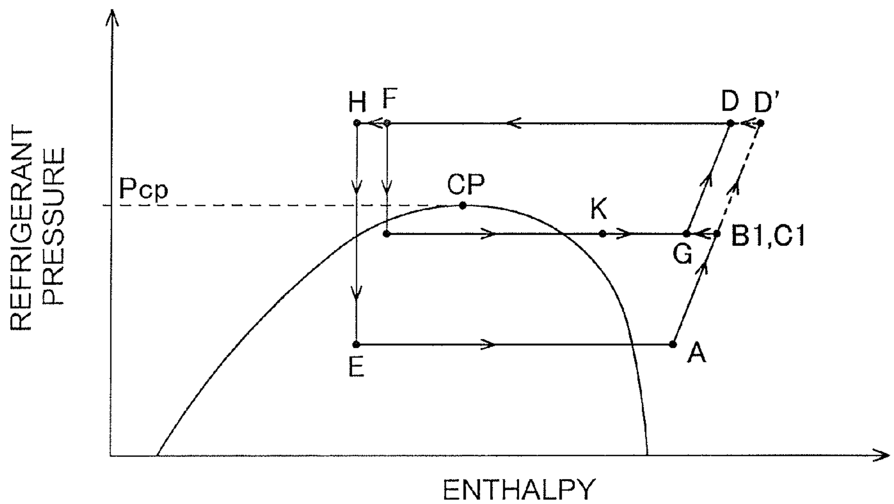
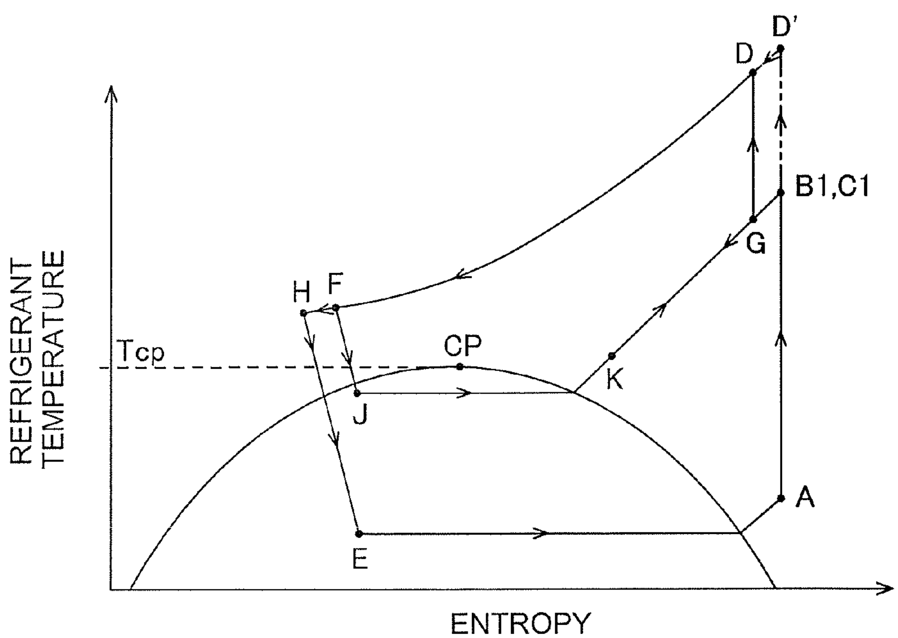

REFRIGERANT TEMPERATURE
Tcp
D'
D
B1
C1
G
H
E
CP
K
J
A
F
ENTROPY

FIG. 15



REFRIGERANT PRESSURE
ENTHALPY
Pcp
CP
H
F
D
D'
K
G
B1,C1
E
A

FIG. 16



REFRIGERANT TEMPERATURE
ENTROPY
Tcp
CP
H
F
D
D'
B1,C1
G
K
J
E
A

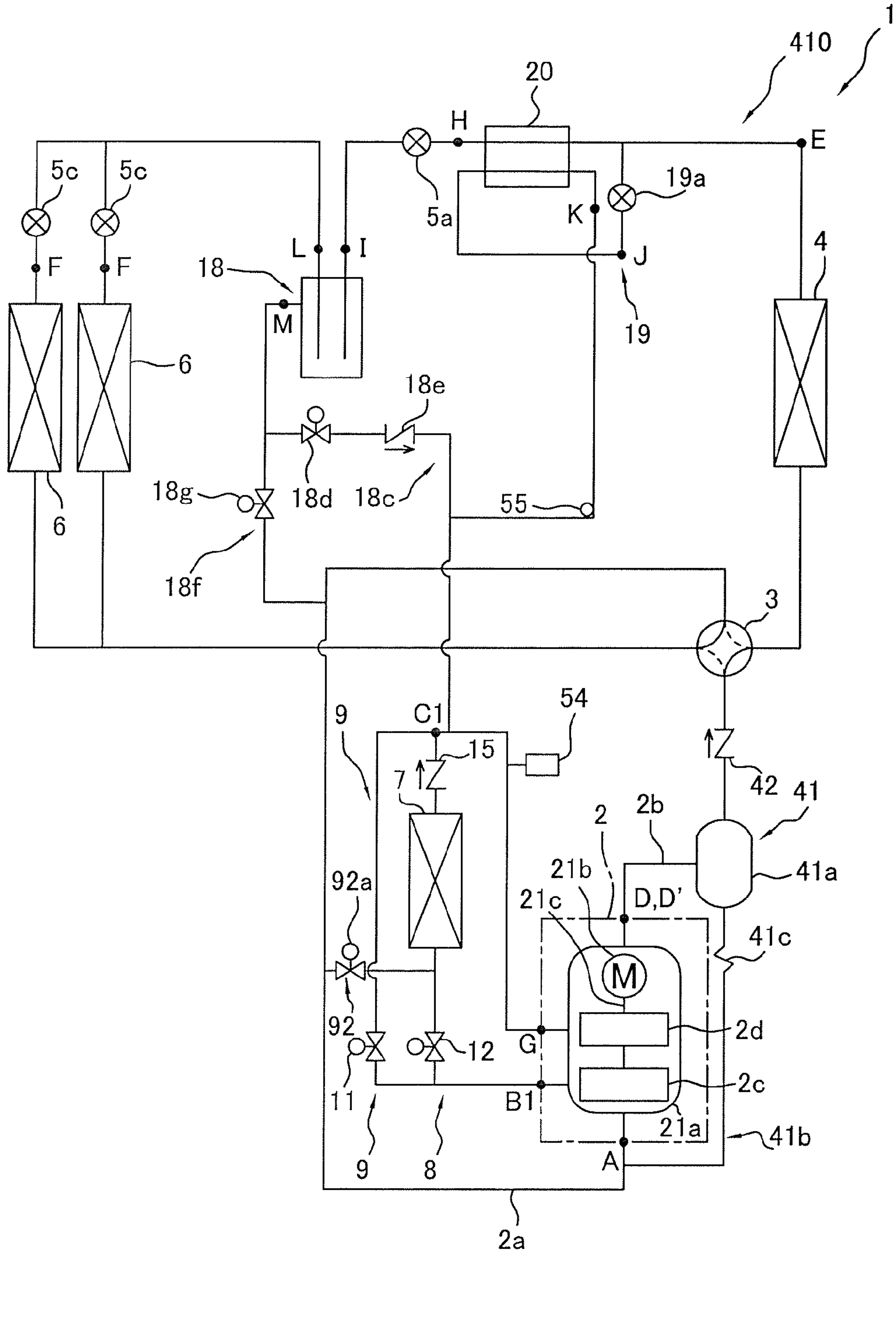

1
410
20
H
E
5c
5c
19a
5a
K
L
I
J
4
F
F
18
19
M
6
18e
18g
18d
18c
55
6
18f
3
54
9
C1
15
7
42
41
2b
2
9
21b
41a
92a
21c
D,D'
41c
M
92
2d
G
12
11
B1
2c
21a
41b
9
8
A
2a

FIG. 17

FIG. 18

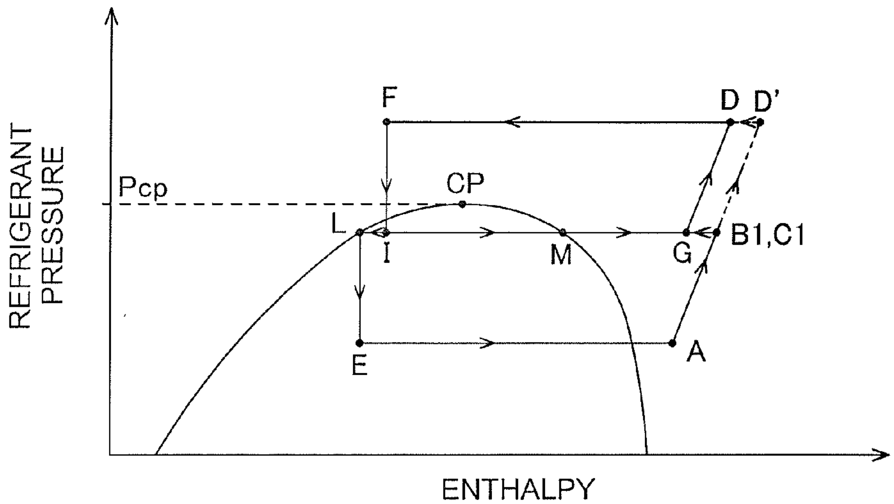
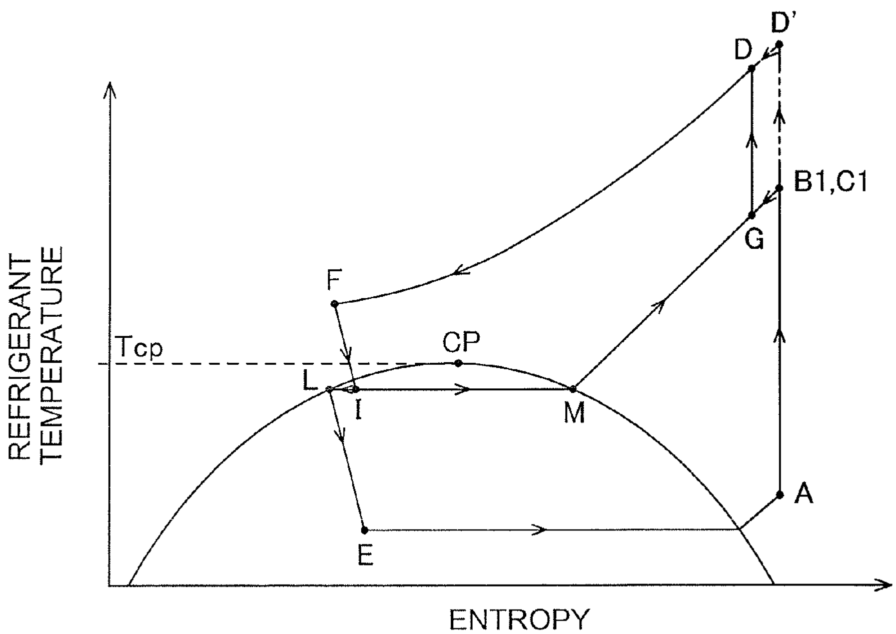
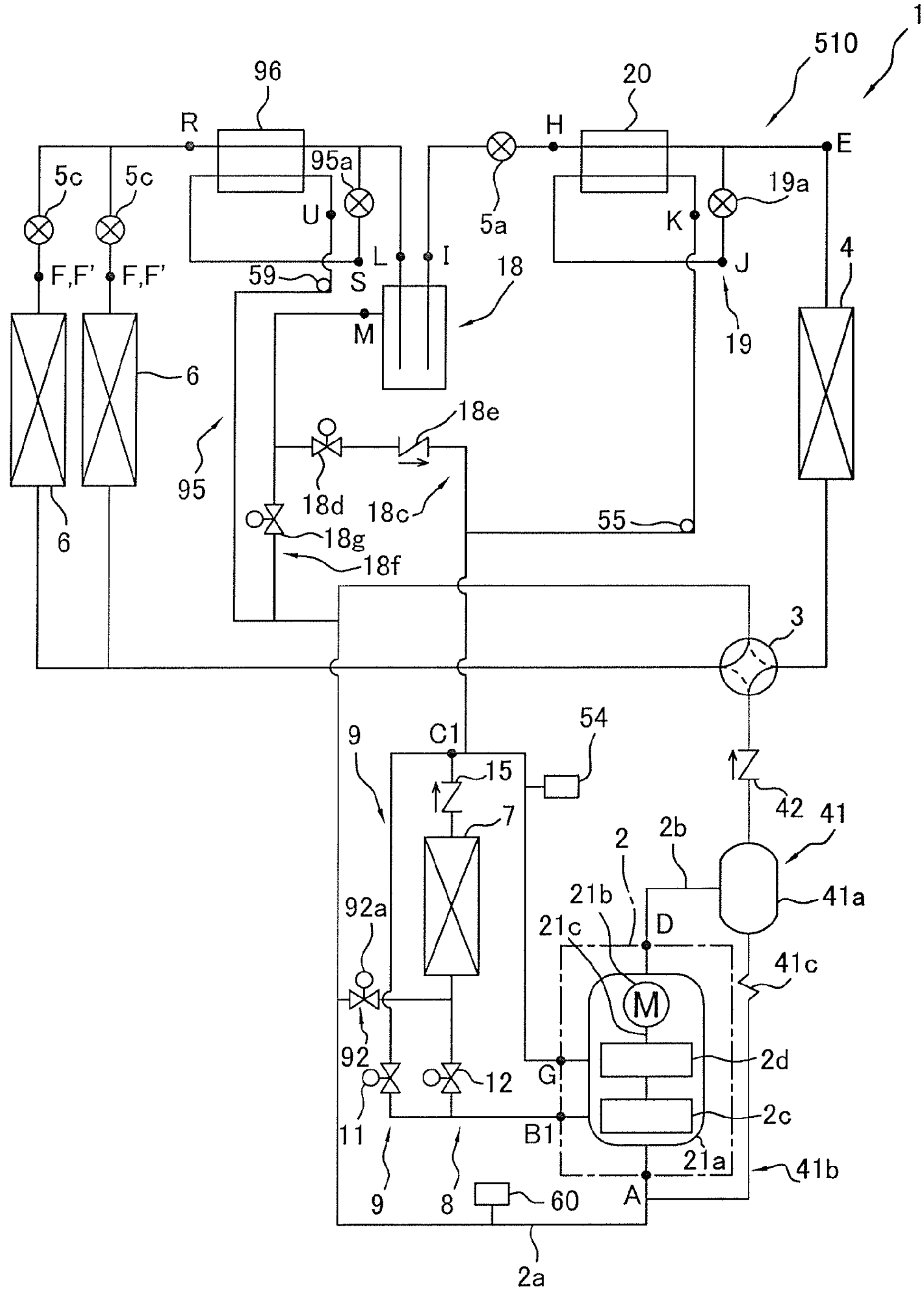

REFRIGERANT PRESSURE
ENTHALPY
Pcp
F
D
D'
CP
L
I
M
G
B1,C1
E
A

FIG. 19


REFRIGERANT TEMPERATURE
ENTROPY
Tcp
D'
D
B1,C1
G
F
CP
L
I
M
A
E


1
510
96
20
R
H
E
5c
5c
95a
19a
U
K
5a
L
I
J
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18
4
M
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6
6
18e
95
18d
18c
55
18g
18f
6
3
54
9
C1
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92a
21b
41a
21c
D
41c
M
92
2d
G
12
11
B1
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41b
9
8
60
A
2a
F,F'
F,F'

FIG. 20

FIG. 21

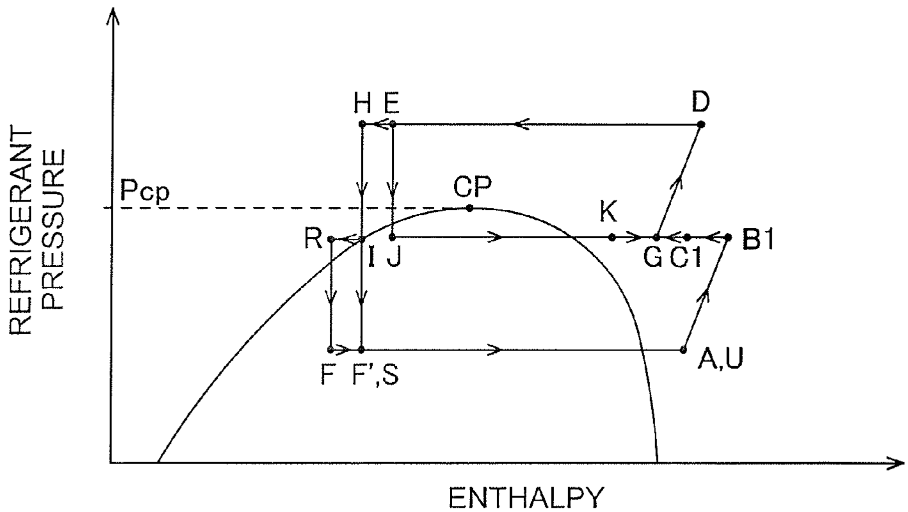
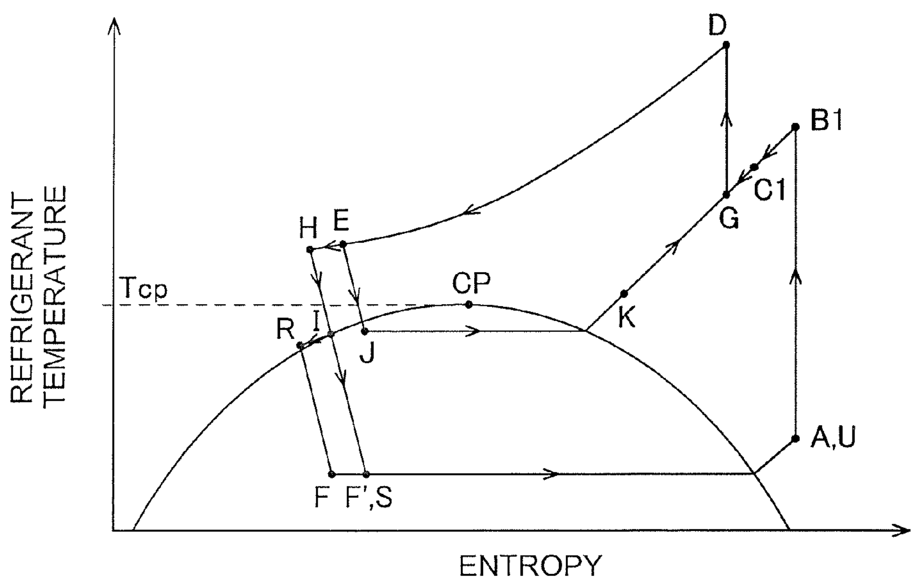

REFRIGERANT PRESSURE
ENTHALPY
Pcp
CP
H
E
D
K
R
I
J
G
C1
B1
F
F',S
A,U

FIG. 22


REFRIGERANT TEMPERATURE
ENTROPY
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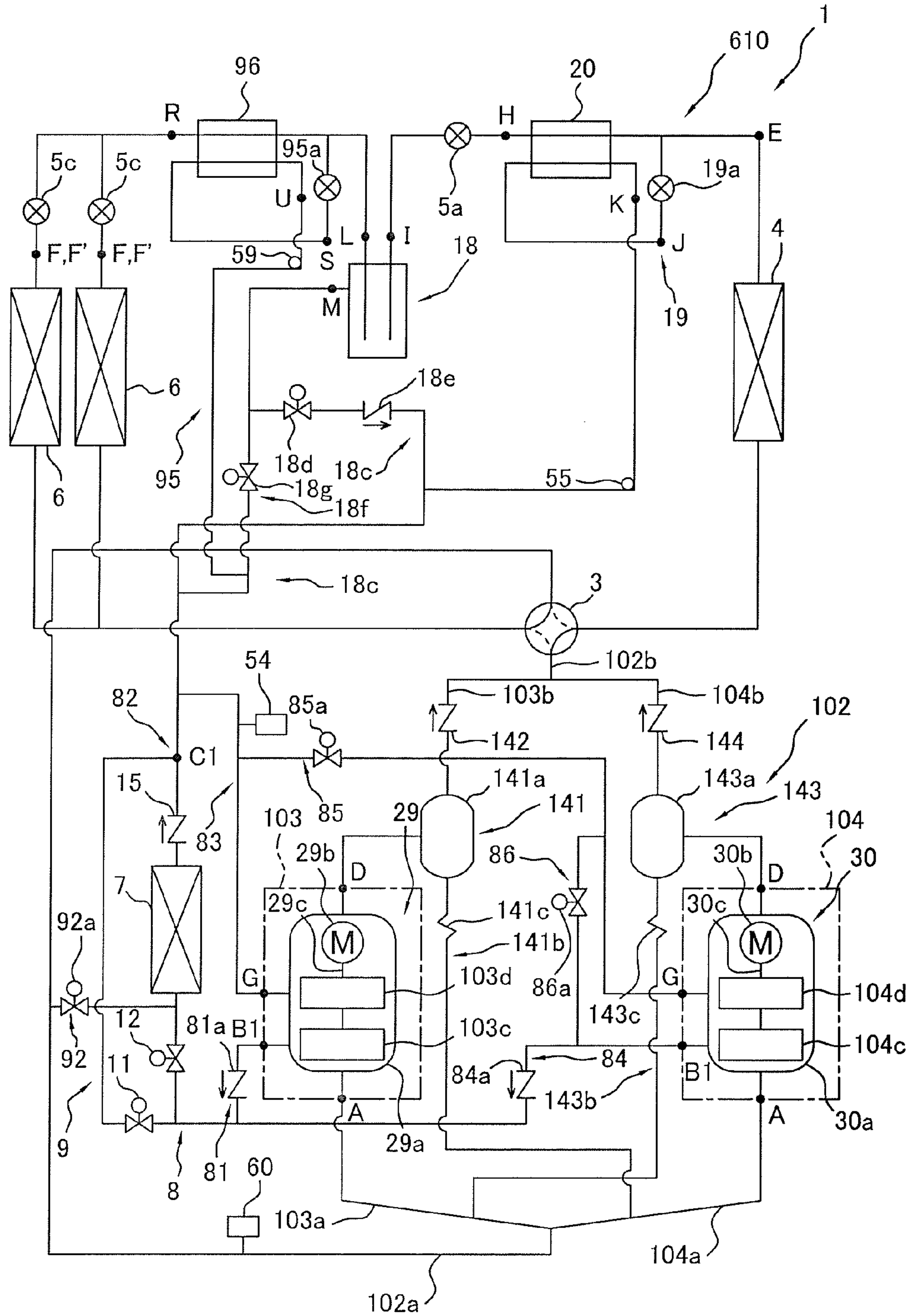
F',S
A,U


1
610
96
20
R
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5c
5c
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5a
19a
U
L
I
K
J
F,F'
F,F'
59
S
18
19
M
4
6
6
18e
95
18d
18c
18g
18f
55
18c
3
102b
54
85a
103b
104b
102
82
C1
142
144
15
83
85
141a
143a
143
141
103
29
104
30
29b
D
86
30b
D
7
29c
141c
30c
M
M
92a
141b
G
103d
86a
143c
G
104d
12
81a
B1
103c
84
104c
92
11
84a
143b
B1
9
A
29a
A
30a
8
81
60
103a
104a
102a

FIG. 23

REFRIGERATION APPARATUS HAVING AN INTERCOOLER DISPOSED BETWEEN FIRST AND SECOND STAGES OF A COMPRESSION MECHANISM AND AN INTERCOOLER BYPASS TUBE TO BYPASS THE INTERCOOLER

CROSS-REFERENCE TO RELATED APPLICATIONS

This U.S. National stage application claims priority under 35 U.S.C. §119(a) to Japanese Patent Application No. 2008-048903, filed in Japan on Feb. 29, 2008, the entire contents of which are hereby incorporated herein by reference.

TECHNICAL FIELD

The present invention relates to a refrigeration apparatus, and particularly relates to a refrigeration apparatus which performs a multistage compression refrigeration cycle.

BACKGROUND ART

As one conventional example of a refrigeration apparatus which performs a multistage compression refrigeration cycle, Japanese Laid-open Patent Publication No. 2007-232263discloses an air-conditioning apparatus which performs a two-stage compression refrigeration cycle. This air-conditioning apparatus primarily has a compressor having two compression elements connected in series, an outdoor heat exchanger, and an indoor heat exchanger.

SUMMARY

A refrigeration apparatus according to a first aspect of the present invention comprises a compression mechanism, a heat source-side heat exchanger, a usage-side heat exchanger, an intercooler, an intercooler bypass tube, and an intake return tube. The compression mechanism has a plurality of compression elements and is configured so that the refrigerant discharged from a first-stage compression element, which is one of the plurality of compression elements, is sequentially compressed by a second-stage compression element. As used herein, the term "compression mechanism" refers to a compressor in which a plurality of compression elements are integrally incorporated, or a configuration wherein includes a compression mechanism in which a single compression element is incorporated and/or a plurality of compression mechanisms in which a plurality of compression elements have been incorporated are connected together. The phrase "the refrigerant discharged from the first-stage compression element, which is one of the plurality of compression elements, is sequentially compressed by the second-stage compression element" does not mean merely that two compression elements connected in series are included, namely, the "first-stage compression element" and the "second-stage compression element;" but means that a plurality of compression elements are connected in series and the relationship between the compression elements is the same as the relationship between the aforementioned "first-stage compression element" and "second-stage compression element." The intercooler is provided to an intermediate refrigerant tube for drawing refrigerant discharged from the first-stage compression element into the second-stage compression element, and the intercooler functions as a cooler of the refrigerant discharged from the first-stage compression element and drawn into the second-stage compression element. The intercooler bypass tube is connected to the intermediate refrigerant tube so as to bypass the intercooler. The intake return tube is a refrigerant tube for connecting the intercooler and the intake side of the compression mechanism during a state in which the refrigerant discharged from the first-stage compression element is drawn into the second-stage compression element through the intercooler bypass tube.

In the conventional air conditioning apparatus, since the refrigerant discharged from the first-stage compression element of the compressor is drawn into the second-stage compression element of the compressor and further compressed, the temperature of the refrigerant discharged from the second-stage compression element of the compressor increases, and in the outdoor heat exchanger that functions as a radiator for the refrigerant, for example, there is a large difference in temperature between the refrigerant and the air and/or water used as the heat source, and increased heat radiation loss in the outdoor heat exchanger reduces the operating efficiency.

As a countermeasure to such problems, the intercooler which functions as a cooler of the refrigerant discharged from the first-stage compression element and drawn into the second-stage compression element is provided to the intermediate refrigerant tube for drawing refrigerant discharged from the first-stage compression element into the second-stage compression element, thereby lowering the temperature of the refrigerant drawn into the second-stage compression element. As a result, it is possible to reduce the temperature of the refrigerant discharged from the second-stage compression element, and heat radiation loss in the outdoor heat exchanger can be reduced.

However, there is a risk of liquid refrigerant accumulating in this intercooler at such times as when the refrigeration apparatus is stopped, and when operation is started in a state in which liquid refrigerant has accumulated in the intercooler, since the liquid refrigerant accumulated in the intercooler is drawn into the second-stage compression element, liquid compression occurs in the second-stage compression element, and the reliability of the compressor is reduced.

Therefore, in the refrigeration apparatus of the present invention, the intercooler bypass tube causes the refrigerant discharged from the first-stage compression element to flow so as to be drawn into the second-stage compression element without passing through the intercooler, the intercooler and the intake side of the compression mechanism are connected by the intake return tube, and the pressure of the refrigerant in the intercooler is reduced to a value near the low pressure of the refrigeration cycle so that the refrigerant in the intercooler can be drawn out to the intake side of the compression mechanism. Therefore, at such times as when the refrigeration apparatus is stopped, even when liquid refrigerant has accumulated inside the intercooler, the liquid refrigerant accumulated in the intercooler can be drawn out to the outside of the intercooler without being drawn into the second-stage compression element. When the refrigeration apparatus is operated in a state in which the intercooler bypass tube causes the refrigerant discharged from the first-stage compression element to be drawn into the second-stage compression element without passing through the intercooler, connecting the intercooler and the intake side of the compression mechanism by using the intake return tube creates a state in which liquid refrigerant does not readily accumulate in the intercooler. Through this configuration, the liquid compression in the second-stage compression element that was caused by accumulation of liquid refrigerant in the intercooler does not occur in the refrigeration apparatus, and the reliability of the compression mechanism can be enhanced.

A refrigeration apparatus according to a second aspect of the present invention is the refrigeration apparatus according to the first aspect of the present invention, further comprising a switching mechanism for switching between a cooling operation state in which refrigerant is circulated in sequence through the compression mechanism, the heat source-side heat exchanger, and the usage-side heat exchanger, and a heating operation state in which refrigerant is circulated in sequence through the compression mechanism, the usage-side heat exchanger, and the heat source-side heat exchanger; wherein the refrigerant discharged from the first-stage compression element is drawn into the second-stage compression element through the intercooler bypass tube, and the intercooler and the intake side of the compression mechanism are connected via the intake return tube at the start of operation in which the switching mechanism is in the cooling operation state.

This refrigeration apparatus is configured so that the refrigerant discharged from the first-stage compression element is drawn into the second-stage compression element through the intercooler bypass tube, and the intercooler and the intake side of the compression mechanism are connected via the intake return tube at the start of operation in which the switching mechanism is in the cooling operation state. Therefore, even when liquid refrigerant is accumulated in the intercooler prior to the start of operation in which the switching mechanism is in the cooling operation state, the liquid refrigerant can be drawn out to the outside of the intercooler. It is thereby possible to prevent a state in which liquid refrigerant is accumulated in the intercooler at the start of operation in which the switching mechanism is in the cooling operation state, and the refrigerant discharged from the first-stage compression element can be drawn into the second-stage compression element via the intercooler without liquid compression occurring in the second-stage compression element due to accumulation of liquid refrigerant in the intercooler.

A refrigeration apparatus according to a third aspect of the present invention is the refrigeration apparatus according to the first or second aspect of the present invention, further comprising a switching mechanism for switching between a cooling operation state in which refrigerant is circulated in sequence through the compression mechanism, the heat source-side heat exchanger, and the usage-side heat exchanger, and a heating operation state in which refrigerant is circulated in sequence through the compression mechanism, the usage-side heat exchanger, and the heat source-side heat exchanger; wherein the refrigerant discharged from the first-stage compression element is drawn into the second-stage compression element through the intercooler bypass tube, and the intercooler and the intake side of the compression mechanism are connected via the intake return tube when the switching mechanism is in the heating operation state.

This refrigeration apparatus is configured so that the refrigerant discharged from the first-stage compression element is drawn into the second-stage compression element through the intercooler bypass tube, and the intercooler and the intake side of the compression mechanism are connected via the intake return tube when the switching mechanism is in the heating operation state. It is therefore possible to prevent heat radiation loss to the outside from the intercooler when the switching mechanism is in the heating operation state, and a state can be created in which liquid refrigerant does not readily accumulate in the intercooler. A reduction in heating performance in the usage-side heat exchanger can thereby be suppressed when the switching mechanism is in the heating operation state, liquid refrigerant can be prevented from accumulating in the intercooler at the start of operation in which the switching mechanism is in the cooling operation state, and the refrigerant discharged from the first-stage compression element can be drawn into the second-stage compression element via the intercooler without liquid compression occurring in the second-stage compression element due to accumulation of liquid refrigerant in the intercooler.

A refrigeration apparatus according to a fourth aspect of the present invention is the refrigeration apparatus according to any of the first through third aspects of the present invention, further comprising an intercooler switching valve capable of switching between a refrigerant non-return state wherein the refrigerant discharged from the first-stage compression element is drawn into the second-stage compression element via the intercooler, and the intercooler and the intake side of the compression mechanism are not connected via the intake return tube; and a refrigerant return state wherein the refrigerant discharged from the first-stage compression element is drawn into the second-stage compression element through the intercooler bypass tube, and the intercooler and the intake side of the compression mechanism are connected via the intake return tube.

In this refrigeration apparatus, since the intercooler switching valve is capable of switching between a refrigerant non-return state and a refrigerant return state, the number of valves can be reduced in comparison to a configuration in which a refrigerant non-return state and a refrigerant return state are switched by a plurality of valves.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1** is a schematic structural diagram of an air-conditioning apparatus as an embodiment of the refrigeration apparatus according to the present invention.

FIG. **2** is a pressure-enthalpy graph representing the refrigeration cycle during the air-cooling operation.

FIG. **3** is a temperature-entropy graph representing the refrigeration cycle during the air-cooling operation.

FIG. **4** is a flowchart of the air-cooling start control.

FIG. **5** is a diagram showing the flow of refrigerant within the air-conditioning apparatus during the air-cooling start control.

FIG. **6** is a schematic structural diagram of an air-conditioning apparatus according to Modification 1.

FIG. **7** is a schematic structural diagram of an air-conditioning apparatus according to Modification 2.

FIG. **8** is a diagram showing the flow of refrigerant within the air-conditioning apparatus during the air-cooling start control.

FIG. **9** is a pressure-enthalpy graph representing the refrigeration cycle during the air-warming operation in the air-conditioning apparatus according to Modification 2.

FIG. **10** is a temperature-entropy graph representing the refrigeration cycle during the air-warming operation in the air-conditioning apparatus according to Modification 2.

FIG. **11** is a diagram showing the flow of refrigerant within the air-conditioning apparatus during the air-warming operation.

FIG. **12** is a schematic structural diagram of an air-conditioning apparatus according to Modification 3.

FIG. **13** is a pressure-enthalpy graph representing the refrigeration cycle during the air-cooling operation in the air-conditioning apparatus according to Modification 3.

FIG. **14** is a temperature-entropy graph representing the refrigeration cycle during the air-cooling operation in the air-conditioning apparatus according to Modification 3.

FIG. **15** is a pressure-enthalpy graph representing the refrigeration cycle during the air-warming operation in the air-conditioning apparatus according to Modification 3.

FIG. **16** is a temperature-entropy graph representing the refrigeration cycle during the air-warming operation in the air-conditioning apparatus according to Modification 3.

FIG. **17** is a schematic structural diagram of an air-conditioning apparatus according to Modification 4.

FIG. **18** is a pressure-enthalpy graph representing the refrigeration cycle during the air-warming operation in the air-conditioning apparatus according to Modification 4.

FIG. **19** is a temperature-entropy graph representing the refrigeration cycle during the air-warming operation in the air-conditioning apparatus according to Modification 4.

FIG. **20** is a schematic structural diagram of an air-conditioning apparatus according to Modification 5.

FIG. **21** is a pressure-enthalpy graph representing the refrigeration cycle during the air-cooling operation in the air-conditioning apparatus according to Modification 5.

FIG. **22** is a temperature-entropy graph representing the refrigeration cycle during the air-cooling operation in the air-conditioning apparatus according to Modification 5.

FIG. **23** is a schematic structural diagram of an air-conditioning apparatus according to Modification 6.

DETAILED DESCRIPTION OF EMBODIMENT(S)

Embodiments of the refrigeration apparatus according to the present invention are described hereinbelow with reference to the drawings.

(1) Basic Configuration of Air-Conditioning Apparatus

FIG. **1** is a schematic structural diagram of an air-conditioning apparatus **1** as an embodiment of the refrigeration apparatus according to the present invention. The air-conditioning apparatus **1** has a refrigerant circuit **10** configured so as to be capable of an air-cooling operation, and the apparatus performs a two-stage compression refrigeration cycle by using a refrigerant (carbon dioxide in this case) for operating in a supercritical range.

The refrigerant circuit **10** of the air-conditioning apparatus **1** has primarily a compression mechanism **2**, a heat source-side heat exchanger **4**, an expansion mechanism **5**, a usage-side heat exchanger **6**, and an intercooler **7**.

In the present embodiment, the compression mechanism **2** is configured from a compressor **21** which uses two compression elements to subject a refrigerant to two-stage compression. The compressor **21** has a hermetic structure in which a compressor drive motor **21***b*, a drive shaft **21***c*, and compression elements **2***c*, **2***d* are housed within a casing **21***a*. The compressor drive motor **21***b* is linked to the drive shaft **21***c*. The drive shaft **21***c* is linked to the two compression elements **2***c*, **2***d*. Specifically, the compressor **21** has a so-called single-shaft, two-stage compression structure in which the two compression elements **2***c*, **2***d* are linked to the single drive shaft **21***c* and the two compression elements **2***c*, **2***d* are both rotatably driven by the compressor drive motor **21***b*. In the present embodiment, the compression elements **2***c*, **2***d* are rotary elements, scroll elements, or another type of positive displacement compression elements. The compressor **21** is configured so as to suck refrigerant through an intake tube **2***a*, to discharge this refrigerant to an intermediate refrigerant tube **8** after the refrigerant has been compressed by the compression element **2***c*, to suck the refrigerant discharged to the intermediate refrigerant tube **8** into the compression element **2***d*, and to discharge the refrigerant to a discharge tube **2***b* after the refrigerant has been further compressed. The intermediate refrigerant tube **8** is a refrigerant tube for taking refrigerant into the compression element **2***d* connected to the second-stage side of the compression element **2***c* after the refrigerant has been discharged at an intermediate pressure in the refrigeration cycle from the compression element **2***c* connected to the first-stage side of the compression element **2***d*. The discharge tube **2***b* is a refrigerant tube for feeding refrigerant discharged from the compression mechanism **2** to the heat source-side heat exchanger **4** as a radiator, and the discharge tube **2***b* is provided with an oil separation mechanism **41** and a non-return mechanism **42**. The oil separation mechanism **41** is a mechanism for separating refrigerator oil accompanying the refrigerant from the refrigerant discharged from the compression mechanism **2** and returning the oil to the intake side of the compression mechanism **2**, and the oil separation mechanism **41** has primarily an oil separator **41***a* for separating refrigerator oil accompanying the refrigerant from the refrigerant discharged from the compression mechanism **2**, and an oil return tube **41***b* connected to the oil separator **41***a* for returning the refrigerator oil separated from the refrigerant to the intake tube **2***a* of the compression mechanism **2**. The oil return tube **41***b* is provided with a pressure-reducing mechanism **41***c* for depressurizing the refrigerator oil flowing through the oil return tube **41***b*. A capillary tube is used for the pressure-reducing mechanism **41***c* in the present embodiment. The non-return mechanism **42** is a mechanism for allowing the flow of refrigerant from the discharge side of the compression mechanism **2** to the heat source-side heat exchanger **4** as a radiator and for blocking the flow of refrigerant from the heat source-side heat exchanger **4** as a radiator to the discharge side of the compression mechanism **2**, and a non-return valve is used in the present embodiment.

Thus, in the present embodiment, the compression mechanism **2** has two compression elements **2***c*, **2***d* and is configured so that among these compression elements **2***c*, **2***d*, refrigerant discharged from the first-stage compression element is compressed in sequence by the second-stage compression element.

The heat source-side heat exchanger **4** is a heat exchanger that functions as a refrigerant radiator. One end of the heat source-side heat exchanger **4** is connected to the compression mechanism **2**, and the other end is connected to the expansion mechanism **5**. Though not shown in the drawings, the heat source-side heat exchanger **4** is supplied with water or air as a cooling source for conducting heat exchange with the refrigerant flowing through the heat source-side heat exchanger **4**.

The expansion mechanism **5** is a mechanism for depressurizing the refrigerant sent to the usage-side heat exchanger **6** functioning as the evaporator from the heat source-side heat exchanger **4** functioning as the radiator, and an electrically driven expansion valve is used in the present embodiment. One end of the expansion mechanism **5** is connected to the heat source-side heat exchanger **4**, and the other end is connected to the usage-side heat exchanger **6**. In the present embodiment, the high-pressure refrigerant cooled in the heat source-side heat exchanger **4** is depressurized by the expansion mechanism **5** to a pressure near the low pressure of the refrigeration cycle before being sent to the usage-side heat exchanger **6** functioning as the evaporator.

The usage-side heat exchanger **6** is a heat exchanger that functions as an evaporator of refrigerant. One end of the usage-side heat exchanger **6** is connected to the expansion mechanism **5**, and the other end is connected to the compression mechanism **2**. Though not shown in the drawings, the usage-side heat exchanger **6** is supplied with water or air as a heating source for conducting heat exchange with the refrigerant flowing through the usage-side heat exchanger **6**.

The intercooler **7** is provided to the intermediate refrigerant tube **8**, and is a heat exchanger which functions as a cooler of refrigerant discharged from the compression element **2***c* on the first-stage side and drawn into the compression element **2***d*. Though not shown in the drawings, the intercooler **7** is supplied with water or air as a cooling source for conducting heat exchange with the refrigerant flowing through the intercooler **7**. Thus, it is acceptable to say that the intercooler **7** is a cooler that uses an external heat source, meaning that the intercooler does not use the refrigerant that circulates through the refrigerant circuit **10**.

An intercooler bypass tube **9** is connected to the intermediate refrigerant tube **8** so as to bypass the intercooler **7**. This intercooler bypass tube **9** is a refrigerant tube for limiting the flow rate of refrigerant flowing through the intercooler **7**. The intercooler bypass tube **9** is provided with an intercooler bypass on/off valve **11**. The intercooler bypass on/off valve **11** is an electromagnetic valve in the present embodiment. Excluding cases in which temporary operations such as the hereinafter-described air-cooling start control are performed, in the present embodiment the intercooler bypass on/off valve **11** is essentially closed.

An intercooler on/off valve **12** is provided to the intermediate refrigerant tube **8** in the portion extending from the connection with the end of the intercooler bypass tube **9** on the side of the first-stage compression element **2***c* to the inlet of the intercooler **7**. The intercooler on/off valve **12** is a mechanism for limiting the flow rate of refrigerant flowing through the intercooler **7**. The intercooler on/off valve **12** is an electromagnetic valve in the present embodiment. Excluding cases in which temporary operations such as the hereinafter-described air-cooling start control are performed, in the present embodiment the intercooler on/off valve **12** is essentially opened.

The intermediate refrigerant tube **8** is also provided with a non-return mechanism **15** for allowing refrigerant to flow from the discharge side of the first-stage compression element **2***c* to the intake side of the second-stage compression element **2***d* and for blocking the refrigerant from flowing from the intake side of the second-stage compression element **2***d* to the discharge side of the first-stage compression element **2***c*. The non-return mechanism **15** is a non-return valve in the present embodiment. In the present embodiment, the non-return mechanism **15** is provided to the intermediate refrigerant tube **8** in the portion leading away from the outlet of the intercooler **7** toward the part connecting with the end of the intercooler bypass tube **9** toward the second stage compression element **2***d*.

A first intake return tube **92** is also connected to one end (the inlet in this case) of the intermediate refrigerant tube **8** or the intercooler **7**. The first intake return tube **92** is a refrigerant tube for connecting the intercooler **7** and the intake side (the intake tube **2***a* in this case) of the compression mechanism **2** in a state in which the refrigerant discharged from the first-stage compression element **2***c* is drawn into the second-stage compression element **2***d* via the intercooler bypass tube **9**. In the present embodiment, one end of the first intake return tube **92** is connected to the portion extending from the connection of the end of the intercooler bypass tube **9** of the intermediate refrigerant tube **8** on the side of the first-stage compression element **2***c* to the inlet of the intercooler **7**, and the other end of the first intake return tube **92** is connected to the intake side (the intake tube **2***a* in this case) of the compression mechanism **2**. A first intake return on/off valve **92***a* is provided to the first intake return tube **92**. The first intake return on/off valve **92***a* is an electromagnetic valve in the present embodiment. Excluding cases in which temporary operations such as the hereinafter-described air-cooling start control are performed, in the present embodiment the first intake return on/off valve **92***a* is essentially closed.

Through not shown in the drawings, the air-conditioning apparatus **1** has a control unit for controlling the operation of the compression mechanism **2**, the expansion mechanism **5**, the intercooler bypass on/off valve **11**, the intercooler on/off valve **12**, the first intake return on/off valve **92***a*, and other components of the air-conditioning apparatus **1**.

(2) Action of the Air-Conditioning Apparatus

Next, the action of the air-conditioning apparatus **1** of the present embodiment will be described using FIGS. **1** through **5**. FIG. **2** is a pressure-enthalpy graph representing the refrigeration cycle during the air-cooling operation, and FIG. **3** is a temperature-entropy graph representing the refrigeration cycle during the air-cooling operation. FIG. **4** is a flow chart of the air-cooling start control. FIG. **5** is a diagram showing the flow of refrigerant within the air-conditioning apparatus **1** during the air-cooling start control. Operation control and air-cooling start control during the following air-cooling operation are performed by the aforementioned controller (not shown). In the following description, the term "high pressure" means a high pressure in the refrigeration cycle (specifically, the pressure at points D, D', and E in FIGS. **2** and **3**), the term "low pressure" means a low pressure in the refrigeration cycle (specifically, the pressure at points A and F in FIGS. **2** and **3**), and the term "intermediate pressure" means an intermediate pressure in the refrigeration cycle (specifically, the pressure at points B1 and C1 in FIGS. **2** and **3**).

<Air-Cooling Operation>

During air-cooling operation, the opening degree of the expansion mechanism **5** is adjusted. The intercooler on/off valve **12** of the intermediate refrigerant tube **8** is opened, and the intercooler bypass on/off valve **11** of the intercooler bypass tube **9** is closed, whereby the intercooler **7** is made to function as a cooler. The first intake return on/off valve **92***a* of the first intake return tube **92** is closed, thereby creating a state in which the intercooler **7** and the intake side of the compression mechanism **2** are not connected (except during the air-cooling start control described hereinafter).

When the refrigerant circuit **10** is in this state, low-pressure refrigerant (refer to point A in FIGS. **1** through **3**) is drawn into the compression mechanism **2** through the intake tube **2***a*, and after the refrigerant is first compressed to an intermediate pressure by the compression element **2***c*, the refrigerant is discharged to the intermediate refrigerant tube **8** (refer to point B1 in FIGS. **1** through **3**). The intermediate-pressure refrigerant discharged from the first-stage compression element **2***c* is cooled by heat exchange with water or air as a cooling source in the intercooler **7** (refer to point C1 in FIGS. **1** to **3**). The refrigerant cooled in the intercooler **7** is then led to and further compressed in the compression element **2***d* connected to the second-stage side of the compression element **2***c*, and the refrigerant is then discharged from the compression mechanism **2** to the discharge tube **2***b* (refer to point D in FIGS. **1** through **3**). The high-pressure refrigerant discharged from the compression mechanism **2** is compressed by the two-stage compression action of the compression elements **2***c*, **2***d* to a pressure exceeding a critical pressure (i.e., the critical pressure Pcp at the critical point CP shown in FIG. **2**). The high-pressure refrigerant discharged from the compression mechanism **2** flows into the oil separator **41***a* constituting the oil separation mechanism **41**, and the accompanying refrigeration oil is separated. The refrigeration oil separated from the high-pressure refrigerant in the oil separator **41***a* flows into the oil return tube **41***b* constituting the oil separation mechanism **41** wherein it is depressurized by the depressurization mechanism **41**c provided to the oil return tube **41**b, and the oil is then returned to the intake tube **2**a of the compression mechanism **2** and led back into the compression mechanism **2**. Next, having been separated from the refrigeration oil in the oil separation mechanism **41**, the high-pressure refrigerant is passed through the non-return mechanism **42** and fed to the heat source-side heat exchanger **4** functioning as a refrigerant radiator. The high-pressure refrigerant fed to the heat source-side heat exchanger **4** is cooled in the heat source-side heat exchanger **4** by heat exchange with water or air as a cooling source (refer to point E in FIGS. **1** through **3**). The high-pressure refrigerant cooled in the heat source-side heat exchanger **4** is then depressurized by the expansion mechanism **5** to become a low-pressure gas-liquid two-phase refrigerant, which is fed to the usage-side heat exchanger **6** functioning as a refrigerant evaporator (refer to point F in FIGS. **1** through **3**). The low-pressure gas-liquid two-phase refrigerant fed to the usage-side heat exchanger **6** is heated by heat exchange with water or air as a heating source in the usage-side heat exchanger **6**, and the refrigerant evaporates as a result (refer to point A in FIGS. **1** through **3**). The low-pressure refrigerant heated in the usage-side heat exchanger **6** is then led back into the compression mechanism **2**. In this manner the air-cooling operation is performed.

Thus, in the air-conditioning apparatus **1**, the intercooler **7** is provided to the intermediate refrigerant tube **8** for letting refrigerant discharged from the compression element **2**c into the compression element **2**d, and the intercooler on/off valve **12** is opened and the intercooler bypass on/off valve **11** of the intercooler bypass tube **9** is closed during the air-cooling operation, thereby putting the intercooler **7** into a state of functioning as a cooler. Therefore, the refrigerant drawn into the compression element **2**d on the second-stage side of the compression element **2**c decreases in temperature (refer to points B**1** and C**1** in FIG. **3**) and the refrigerant discharged from the compression element **2**d also decreases in temperature (refer to points D and D' in FIG. **3**), in comparison with cases in which no intercooler **7** is provided (in this case, the refrigeration cycle is performed in the sequence in FIGS. **2** and **3**: point A→point B**1**→point D'→point E→point F). Therefore, in the heat source-side heat exchanger **4** functioning as a radiator of high-pressure refrigerant in this air-conditioning apparatus **1**, operating efficiency can be improved over cases in which no intercooler **7** is provided, because the temperature difference between the refrigerant and water or air as the cooling source can be reduced, and heat radiation loss can be reduced by an amount equivalent to the area enclosed by connecting points B**1**, D', D, and C**1** in FIG. **3**.

<Air-Cooling Start Control>

In the intercooler **7** such as the one described above, there is a risk of accumulation of liquid refrigerant at such times as when the air-conditioning apparatus **1** is stopped, and when the air-cooling operation described above is started in a state in which liquid refrigerant has accumulated in the intercooler **7**, since the liquid refrigerant accumulated in the intercooler **7** is drawn into the second-stage compression element **2**d, liquid compression occurs in the second-stage compression element **2**d, and the reliability of the compression mechanism **2** is reduced.

Therefore, in the present embodiment, air-cooling start control is performed so that the refrigerant discharged from the first-stage compression element **2**c is drawn into the second-stage compression element **2**d through the intercooler bypass tube **9**, and the intercooler **7** and the intake side of the compression mechanism **2** are connected by the first intake return tube **92** at the start of the air-cooling operation described above.

The air-cooling start control of the present embodiment is described in detail hereinbelow using FIGS. **4** and **5**.

First, when a command is issued in step S**1** to start air-cooling operation, the process proceeds to step S**2**, in which the various valves are operated.

Then, in step S**2**, the on/off states of the on/off valves **11**, **12**, **92**a are switched to the refrigerant return state in which the refrigerant discharged from the first-stage compression element **2**c is drawn into the second stage compression element **2**d via the intercooler bypass tube **9**, and the intercooler **7** and the intake side of the compression mechanism **2** are connected via the first intake return tube **92**. Specifically, the intercooler bypass on/off valve **11** is opened, and the intercooler on/off valve **12** is closed. The intercooler bypass tube **9** then causes a flow to occur whereby the refrigerant discharged from the first-stage compression element **2**c is drawn into the second-stage compression element **2**d without passing through the intercooler **7**. Specifically, a state is effected in which the intercooler **7** does not function as a cooler, and the refrigerant discharged from the first-stage compression element **2**c is drawn into the second-stage compression element **2**d via the intercooler bypass tube **9** (see FIG. **5**). In such a state, the first intake return on/off valve **92**a is then opened. The intercooler **7** and the intake side of the compression mechanism **2** are then connected by the first intake return tube **92**, and the pressure of the refrigerant in the intercooler **7** (more specifically, the portion between the intercooler on/off valve **12** and the non-return mechanism **15** that includes the intercooler **7**) is reduced to near the low pressure of the refrigeration cycle so that the refrigerant in the intercooler **7** can be drawn out to the intake side of the compression mechanism **2** (see FIG. **5**).

Then, in step S**3**, the on/off states of the on/off valves **11**, **12**, **92**a in step S**2** (i.e., the refrigerant return state) are maintained for a predetermined amount of time. The liquid refrigerant accumulated in the intercooler **7** can thereby be evaporated by depressurization, drawn out to the outside of the intercooler **7** (more specifically, to the intake side of the compression mechanism **2**), and drawn into the compression mechanism **2** (here, the first-stage compression element **2**c) without being drawn into the second-stage compression element **2**d, even when liquid refrigerant has accumulated inside the intercooler **7** at such times as when the air conditioning apparatus **1** is stopped. The predetermined time herein is set to an amount of time sufficient for the liquid refrigerant accumulated in the intercooler **7** to be drawn out to the outside of the intercooler **7**.

Then, in step S**4**, the on/off states of the on/off valves **11**, **12**, **92**a are switched to the refrigerant non-return state in which the refrigerant discharged from the first-stage compression element **2**c is drawn into the second-stage compression element **2**d via the intercooler **7**, and the intercooler **7** and the intake side of the compression mechanism **2** are not connected via the first intake return tube **92**. Specifically, the process transitions to the on/off states of the valves **11**, **12**, **92**a for the air-cooling operation described above, and air-cooling start control is completed. Specifically, the first intake return on/off valve **92**a is closed. A state then arises in which the refrigerant in the intercooler **7** does not flow out to the intake side of the compression mechanism **2**. In such a state, the intercooler on/off valve **12** is opened, and the intercooler bypass on/off valve **11** is closed. The intercooler **7** then functions as a cooler.

Through this configuration, the liquid compression in the second-stage compression element **2**d that was caused by accumulation of liquid refrigerant in the intercooler **7** does not occur in the air-conditioning apparatus **1** at the start of air-cooling operation, and the reliability of the compression mechanism **2** can be enhanced.

(3) Modification 1

In the embodiment described above, switching between air-cooling operation and air-cooling start control, i.e., switching between the refrigerant non-return state and the refrigerant return state, is accomplished by the on/off states of the on/off valves **11**, **12**, **92***a*. However, a refrigerant circuit **110** may be used that is provided with an intercooler switching valve **93** capable of switching between a refrigerant non-return state and a refrigerant return state, instead of the on/off valves **11**, **12**, **92***a*, as shown in FIG. **6**.

Here, the intercooler switching valve **93** is a valve capable of switching between a refrigerant non-return state and a refrigerant return state, and in the present modification, the intercooler switching valve **93** is a four-way switching valve connected to the intermediate refrigerant tube **8** at the discharge side of the first-stage compression element **2***c*, the intermediate refrigerant tube **8** at the inlet side of the intercooler **7**, the end of the intercooler bypass tube **9** on the side of the first-stage compression element **2***c*, and the end of the first intake return tube **92** on the side of the intercooler **7**. The intercooler bypass tube **9** is also provided with a non-return mechanism **9** for allowing refrigerant to flow from the discharge side of the first-stage compression element **2***c* to the intake side of the second-stage compression element **2***d* and for blocking the refrigerant from flowing from the intake side of the second-stage compression element **2***d* to the discharge side of the first-stage compression element **2***c* and the intake side of the compression mechanism **2**. The non-return mechanism **9***a* is a non-return valve in the present modification.

Although not described in detail in the present modification, by switching the intercooler switching valve **93** to the refrigerant non-return state (indicated by solid lines in the intercooler switching valve **93** shown in FIG. **6**) in which the refrigerant discharged from the first-stage compression element **2***c* is drawn into the second-stage compression element **2***d* via the intercooler **7**, and the intercooler **7** and the intake side of the compression mechanism **2** are not connected via the first intake return tube **92**, the same air-cooling operation as that of the embodiment described above is performed. By switching the intercooler switching valve **93** to the refrigerant return state (indicated by dashed lines in the intercooler switching valve **93** shown in FIG. **6**) in which the intercooler **7** and the intake side of the compression mechanism **2** are connected via the first intake return tube **92**, and the refrigerant discharged from the first-stage compression element **2***c* is drawn into the second-stage compression element **2***d* via the intercooler bypass tube **9**, the same air-cooling start control as described in the embodiment above can also be performed.

The same operational effects as those of the embodiment described above can also be achieved with the configuration of the present modification. In the present modification, since it is possible to switch between the refrigerant non-return state and the refrigerant return state by using the intercooler switching valve **93**, the number of valves can be reduced in comparison to a configuration in which a refrigerant non-return state and a refrigerant return state are switched by the plurality of valves **11**, **12**, **92***a* as described in the above embodiment. Since pressure drop is also reduced relative to a case in which an electromagnetic valve is used, the intermediate pressure of the refrigeration cycle can be prevented from decreasing, and operating efficiency can be prevented from decreasing as well.

(4) Modification 2

In the embodiment and modification thereof described above, the air-conditioning apparatus **1** which performs a two-stage compression refrigeration cycle and is capable of air-cooling operation is provided with the intercooler **7** for functioning as a cooler for refrigerant discharged from the first-stage compression element **2***c* and drawn into the second-stage compression element **2***d*; the intercooler bypass tube **9** connected to the intermediate refrigerant tube **8** so as to bypass the intercooler **7**; and the first intake return tube **92** for connecting the intercooler **7** and the intake side of the compression mechanism **2** during a state in which the refrigerant discharged from the first-stage compression element **2***c* is drawn into the second-stage compression element **2***d* via the intercooler bypass tube **9**. However, this configuration may also be configured to be capable of switching between air-cooling operation and air-warming operation.

For example, the refrigerant circuit **10** (see FIG. **1**) of the embodiment described above which employs a two-stage compression-type compression mechanism **2** may be modified to create a refrigerant circuit **210** in which a switching mechanism **3** is provided for enabling switching between air-cooling operation and air-warming operation, a first expansion mechanism **5***a* and a second expansion mechanism **5***b* are provided instead of the expansion mechanism **5**, and a bridge circuit **17** and a receiver **18** are provided, as shown in FIG. **7**.

The switching mechanism **3** is a mechanism for switching the direction of refrigerant flow in the refrigerant circuit **210**. In order to allow the heat source-side heat exchanger **4** to function as a radiator of refrigerant discharged from the compression mechanism **2** and to allow the usage-side heat exchanger **6** to function as an evaporator of refrigerant cooled in the heat source-side heat exchanger **4** during the air-cooling operation, the switching mechanism **3** is capable of connecting the discharge side of the compression mechanism **2** and one end of the heat source-side heat exchanger **4** and also connecting the intake side of the compressor **21** and the usage-side heat exchanger **6** (refer to the solid lines of the switching mechanism **3** in FIG. **7**, this state of the switching mechanism **3** is hereinbelow referred to as the "cooling operation state"). In order to allow the usage-side heat exchanger **6** to function as a radiator of refrigerant discharged from the compression mechanism **2** and to allow the heat source-side heat exchanger **4** to function as an evaporator of refrigerant cooled in the usage-side heat exchanger **6** during the air-warming operation, the switching mechanism **3** is capable of connecting the discharge side of the compression mechanism **2** and the usage-side heat exchanger **6** and also of connecting the intake side of the compression mechanism **2** and one end of the heat source-side heat exchanger **4** (refer to the dashed lines of the switching mechanism **3** in FIG. **7**, this state of the switching mechanism **3** is hereinbelow referred to as the "heating operation state"). In the present modification, the switching mechanism **3** is a four-way switching valve connected to the intake side of the compression mechanism **2**, the discharge side of the compression mechanism **2**, the heat source-side heat exchanger **4**, and the usage-side heat exchanger **6**. The switching mechanism **3** is not limited to a four-way switching valve, and may be configured so as to have a function for switching the direction of the flow of the refrigerant in the same manner as described above by using, e.g., a combination of a plurality of electromagnetic valves.

Thus, the switching mechanism **3** is configured so as to be capable of switching between the cooling operation state in which refrigerant is circulated in sequence through the compression mechanism **2**, the heat source-side heat exchanger **4**, the first expansion mechanism **5***a*, the receiver **18**, the second expansion mechanism **5***b*, and the usage-side heat exchanger **6**; and the heating operation state in which refrigerant is circulated in sequence through the compression mechanism **2**, the usage-side heat exchanger **6**, the first expansion mechanism **5***a*, the receiver **18**, the second expansion mechanism **5***b*, and the heat source-side heat exchanger **4**.

The bridge circuit **17** is disposed between the heat source-side heat exchanger **4** and the usage-side heat exchanger **6**, and is connected to a receiver inlet tube **18***a* connected to the inlet of the receiver **18** and to a receiver outlet tube **18***b* connected to the outlet of the receiver **18**. The bridge circuit **17** has four non-return valves **17***a*, **17***b*, **17***c* and **17***d* in the present modification. The inlet non-return valve **17***a* is a non-return valve that allows only the flow of refrigerant from the heat source-side heat exchanger **4** to the receiver inlet tube **18***a*. The inlet non-return valve **17***b* is a non-return valve that allows only the flow of refrigerant from the usage-side heat exchanger **6** to the receiver inlet tube **18***a*. In other words, the inlet non-return valves **17***a*, **17***b* have a function for allowing refrigerant to flow from either the heat source-side heat exchanger **4** or the usage-side heat exchanger **6** to the receiver inlet tube **18***a*. The outlet non-return valve **17***c* is a non-return valve that allows only the flow of refrigerant from the receiver outlet tube **18***b* to the usage-side heat exchanger **6**. The outlet non-return valve **17***d* is a non-return valve that allows only the flow of refrigerant from the receiver outlet tube **18***b* to the heat source-side heat exchanger **4**. In other words, the outlet non-return valves **17***c*, **17***d* have a function for allowing refrigerant to flow from the receiver outlet tube **18***b* to either the heat source-side heat exchanger **4** or the usage-side heat exchanger **6**.

The first expansion mechanism **5***a* is a mechanism for depressurizing the refrigerant, is provided to the receiver inlet tube **18***a*, and is an electrically driven expansion valve in the present modification. In the present modification, during air-cooling operation, the high-pressure refrigerant cooled in the heat source-side heat exchanger **4** is depressurized by the first expansion mechanism **5***a* to near the saturation pressure of the refrigerant before being sent to the usage-side heat exchanger **6** via the receiver **18**, and during air-warming operation, the high-pressure refrigerant cooled in the usage-side heat exchanger **6** is depressurized by the first expansion mechanism **5***a* to near the saturation pressure of the refrigerant before being sent to the heat source-side heat exchanger **4** via the receiver **18**.

The receiver **18** is a container provided to temporarily retain the refrigerant that has been depressurized by the first expansion mechanism **5***a*, so that it is possible to retain excess refrigerant that forms according to operating conditions such as differences in the flow rate of refrigerant circulated in the refrigerant circuit **210** between air-cooling operation and air-warming operation. The inlet of the receiver **18** is connected to the receiver inlet tube **18***a*, and the outlet of the receiver **18** is connected to the receiver outlet tube **18***b*. Also connected to the receiver **18** is a second intake return tube **18***f* capable of withdrawing refrigerant from inside the receiver **18** and returning the refrigerant to the intake tube **2***a* of the compression mechanism **2** (i.e., to the intake side of the compression element **2***c* on the first-stage side of the compression mechanism **2**). A second intake return on/off valve **18***g* is provided to the second intake return tube **18***f*. The second intake return on/off valve **18***g* is an electromagnetic valve in the present modification.

The second expansion mechanism **5***b* is a mechanism provided to the receiver outlet tube **18***b* and used for depressurizing the refrigerant, and is an electrically driven expansion valve in the present modification. In the present modification, during air-cooling operation, the refrigerant depressurized by the first expansion mechanism **5***a* is further depressurized by the second expansion mechanism **5***b* to the low pressure of the refrigeration cycle before being sent to the usage-side heat exchanger **6** via the receiver **18**, and during air-warming operation, the refrigerant depressurized by the first expansion mechanism **5***a* is further depressurized by the second expansion mechanism **5***b* to the low pressure of the refrigeration cycle before being sent to the heat source-side heat exchanger **4** via the receiver **18**.

By using the bridge circuit **17**, the receiver **18**, the receiver inlet tube **18***a*, and the receiver outlet tube **18***b* in the present modification, when the switching mechanism **3** is brought to the cooling operation state, the high-pressure refrigerant cooled in the heat source-side heat exchanger **4** can be fed to the usage-side heat exchanger **6** through the inlet non-return valve **17***a* of the bridge circuit **17**, the first expansion mechanism **5***a* of the receiver inlet tube **18***a*, the receiver **18**, the second expansion mechanism **5***b* of the receiver outlet tube **18***b*, and the outlet non-return valve **17***c* of the bridge circuit **17**. When the switching mechanism **3** is brought to the heating operation state, the high-pressure refrigerant cooled in the usage-side heat exchanger **6** can be fed to the heat source-side heat exchanger **4** through the inlet non-return valve **17***b* of the bridge circuit **17**, the first expansion mechanism **5***a* of the receiver inlet tube **18***a*, the receiver **18**, the second expansion mechanism **5***b* of the receiver outlet tube **18***b*, and the outlet non-return valve **17***d* of the bridge circuit **17**.

During air-cooling operation in which the switching mechanism **3** is in the cooling operation state, the intercooler bypass on/off valve **11** of the intercooler bypass tube **9** is controlled so as to close (except for during air-cooling start control), the same as in the embodiment and modification thereof described above, and during air-warming operation in which the switching mechanism **3** is in the heating operation state, the intercooler bypass on/off valve **11** of the intercooler bypass tube **9** is controlled so as to open. During air-cooling operation in which the switching mechanism **3** is in the cooling operation state, the intercooler on/off valve **12** of the intermediate refrigerant tube **8** is controlled so as to open (except for during air-cooling start control), the same as in the embodiment and modification thereof described above, and during air-warming operation in which the switching mechanism **3** is in the heating operation state, the intercooler on/off valve **12** of the intermediate refrigerant tube **8** is controlled so as to close. Moreover, the first intake return on/off valve **92***a* of the first intake return tube **92** is controlled so as to open not only during air-cooling start control, but during air-warming operation in which the switching mechanism **3** is in the heating operation state.

Next, the action of the air-conditioning apparatus **1** of the present modification will be described using FIGS. **7**, **2** through **4**, and **8** through **11**. FIG. **8** is a diagram showing the flow of refrigerant within the air-conditioning apparatus **1** during the air-cooling start control, FIG. **9** is a pressure-enthalpy graph representing the refrigeration cycle during the air-warming operation, FIG. **10** is a temperature-entropy graph representing the refrigeration cycle during the air-warming operation, and FIG. **11** is a diagram showing the flow of refrigerant within the air-conditioning apparatus **1** during the air-warming operation. The air-cooling start control and the refrigeration cycle during air-cooling operation will be described using FIGS. **2** through **4**. Operational control of the air-cooling operation, air-cooling start control, and air-warming operation described below is performed by the control unit (not shown) of the embodiment described above. In the following description, the term "high pressure" means a high pressure in the refrigeration cycle (specifically, the pressure at points D, D', and E in FIGS. **2** and **3**, and the pressure at points D, D', and F in FIGS. **9** and **10**), the term "low pressure" means a low pressure in the refrigeration cycle (specifically, the pressure at points A and F in FIGS. **2** and **3**, and the pressure at points A and E in FIGS. **9** and **10**), and the term "intermediate pressure" means an intermediate pressure in the refrigeration cycle (specifically, the pressure at points B**1**, C**1**, and C**1**' in FIGS. **2**, **3**, **9**, and **10**).

<Air-Cooling Operation>

During the air-cooling operation, the switching mechanism **3** is brought to the cooling operation state shown by the solid lines in FIG. **7**. The opening degrees of the first expansion mechanism **5***a* and the second expansion mechanism **5***b* are also adjusted. Since the switching mechanism **3** is in the cooling operation state, the intercooler on/off valve **12** of the intermediate refrigerant tube **8** is opened, and the intercooler bypass on/off valve **11** of the intercooler bypass tube **9** is closed, whereby the intercooler **7** is caused to function as a cooler. The first intake return on/off valve **92***a* of the first intake return tube **92** is also closed, thereby bringing about a state in which the intercooler **7** and the intake side of the compression mechanism **2** are not connected (except during the air-cooling start control described hereinafter).

When the refrigerant circuit **210** is in this state, low-pressure refrigerant (refer to point A in FIGS. **7**, **2**, and **3**) is drawn into the compression mechanism **2** through the intake tube **2***a*, and after the refrigerant is first compressed to an intermediate pressure by the compression element **2***c*, the refrigerant is discharged to the intermediate refrigerant tube **8** (refer to point B**1** in FIGS. **7**, **2**, **3**). The intermediate-pressure refrigerant discharged from the first-stage compression element **2***c* is cooled by heat exchange with water or air as a cooling source in the intercooler **7** (refer to point C**1** in FIGS. **7**, **2**, and **3**). The refrigerant cooled in the intercooler **7** is then led to and further compressed in the compression element **2***d* connected to the second-stage side of the compression element **2***c*, and the refrigerant is then discharged from the compression mechanism **2** to the discharge tube **2***b* (refer to point D in FIGS. **7**, **2**, and **3**). The high-pressure refrigerant discharged from the compression mechanism **2** is compressed by the two-stage compression action of the compression elements **2***c*, **2***d* to a pressure exceeding a critical pressure (i.e., the critical pressure Pcp at the critical point CP shown in FIG. **2**). The high-pressure refrigerant discharged from the compression mechanism **2** flows into the oil separator **41***a* constituting the oil separation mechanism **41**, and the accompanying refrigeration oil is separated. The refrigeration oil separated from the high-pressure refrigerant in the oil separator **41***a* flows into the oil return tube **41***b* constituting the oil separation mechanism **41** wherein it is depressurized by the depressurization mechanism **41***c* provided to the oil return tube **41***b*, and the oil is then returned to the intake tube **2***a* of the compression mechanism **2** and led back into the compression mechanism **2**. Next, having been separated from the refrigeration oil in the oil separation mechanism **41**, the high-pressure refrigerant is passed through the non-return mechanism **42** and the switching mechanism **3**, and is fed to the heat source-side heat exchanger **4** functioning as a refrigerant radiator. The high-pressure refrigerant fed to the heat source-side heat exchanger **4** is cooled in the heat source-side heat exchanger **4** by heat exchange with water or air as a cooling source (refer to point E in FIGS. **7**, **2**, and **3**). The high-pressure refrigerant cooled in the heat source-side heat exchanger **4** then flows into the receiver inlet tube **18***a* through the inlet non-return valve **17***a* of the bridge circuit **17**, and is depressurized to a pressure near the saturation pressure by the first expansion mechanism **5***a* and temporarily retained in the receiver **18** (refer to point I in FIG. **7**). The refrigerant retained in the receiver **18** is fed to the receiver outlet tube **18***b* and is depressurized by the second expansion mechanism **5***b* to become a low-pressure gas-liquid two-phase refrigerant, and is then fed through the outlet non-return valve **17***c* of the bridge circuit **17** to the usage-side heat exchanger **6** functioning as a refrigerant evaporator (refer to point F in FIGS. **7**, **2**, and **3**). The low-pressure gas-liquid two-phase refrigerant fed to the usage-side heat exchanger **6** is heated by heat exchange with water or air as a heating source, and the refrigerant evaporates as a result (refer to point A in FIGS. **7**, **2**, and **3**). The low-pressure refrigerant heated in the usage-side heat exchanger **6** is then led back into the compression mechanism **2** via the switching mechanism **3**. In this manner the air-cooling operation is performed.

In this manner, in the heat source-side heat exchanger **4** functioning as a radiator of high-pressure refrigerant in the air-conditioning apparatus **1** of the present modification, operating efficiency can be improved over cases in which no intercooler **7** is provided, because the temperature difference between the refrigerant and water or air as the cooling source can be reduced, the same as in the embodiment described above.

<Air-Cooling Start Control>

In the intercooler **7** of the present modification as well, there is a risk of liquid refrigerant accumulating in this intercooler **7** at such times as when the air-conditioning apparatus **1** is stopped, and when the air-cooling operation described above is started in a state in which liquid refrigerant has accumulated in the intercooler **7**, since the liquid refrigerant accumulated in the intercooler **7** is drawn into the second-stage compression element **2***d*, liquid compression occurs in the second-stage compression element **2***d*, and the reliability of the compression mechanism **2** is reduced.

Therefore, in the present modification as well, air-cooling start control is performed so that the refrigerant discharged from the first-stage compression element **2***c* is drawn into the second-stage compression element **2***d* through the intercooler bypass tube **9**, and the intercooler **7** and the intake side of the compression mechanism **2** are connected by the first intake return tube **92** at the start of the air-cooling operation described above, the same as in the embodiment described above.

The air-cooling start control in the present modification is the same as the air-cooling start control in the embodiment described above (refer to FIGS. **4** and **8**), except that the switching mechanism **3** is placed in the cooling operation state in accordance with a command to start air-cooling operation. The air-cooling start control of the present modification therefore will not be described in detail.

Therefore, in the present modification as well, since the refrigerant discharged from the first-stage compression element **2***c* is drawn into the second-stage compression element **2***d* through the intercooler bypass tube **9**, and the intercooler **7** and the intake side of the compression mechanism **2** are connected by the first intake return tube **92** at the start of air-cooling operation in which the switching mechanism **3** is in the cooling operation state, even when liquid refrigerant has accumulated in the intercooler **7** prior to the start of operation with the switching mechanism **3** in the cooling operation state, this liquid refrigerant can be drawn out to the outside of the intercooler **7**, the same as in the embodiment described above. It is thereby possible to prevent a state in which liquid refrigerant has accumulated in the intercooler **7** at the start of operation with the switching mechanism **3** in the cooling operation state, there is no liquid compression in the second-stage compression element **2***d* due to accumulation of the liquid refrigerant in the intercooler **7**, and the reliability of the compression mechanism **2** can be enhanced.

<Air-Warming Operation>

During the air-warming operation, the switching mechanism **3** is brought to the heating operation state shown by the dashed lines in FIGS. **7** and **11**. The opening degrees of the first expansion mechanism **5***a* and the second expansion mechanism **5***b* are also adjusted. Since the switching mechanism **3** is set to a heating operation state, the intercooler on/off valve **12** of the intermediate refrigerant tube **8** is closed and the intercooler bypass on/off valve **11** of the intercooler bypass tube **9** is opened, thereby putting the intercooler **7** into a state of not functioning as a cooler. Furthermore, since the switching mechanism **3** is in the heating operation state, the first intake return on/off valve **92***a* of the first intake return tube **92** is opened, thereby causing the intercooler **7** and the intake side of the compression mechanism **2** to be connected.

When the refrigerant circuit **210** is in this state, low-pressure refrigerant (refer to point A in FIG. **7** and FIGS. **9** through **11**) is drawn into the compression mechanism **2** through the intake tube **2***a*, and after the refrigerant is first compressed to an intermediate pressure by the compression element **2***c*, the refrigerant is discharged to the intermediate refrigerant tube **8** (refer to point B1 in FIG. **7** and FIGS. **9** through **11**). The intermediate-pressure refrigerant discharged from the first-stage compression element **2***c* passes through the intercooler bypass tube **9** (refer to point C1 in FIGS. **7**, and **9** through **11**) without passing through the intercooler **7** (i.e., without being cooled), unlike in the air-cooling operation. The refrigerant is drawn into and further compressed in the compression element **2***d* connected to the second-stage side of the compression element **2***c*, and is discharged from the compression mechanism **2** to the discharge tube **2***b* (refer to point D in FIGS. **7**, and **9** through **11**). The high-pressure refrigerant discharged from the compression mechanism **2** is compressed by the two-stage compression action of the compression elements **2***c*, **2***d* to a pressure exceeding a critical pressure (i.e., the critical pressure Pcp at the critical point CP shown in FIG. **9**), similar to the air-cooling operation. The high-pressure refrigerant discharged from the compression mechanism **2** flows into the oil separator **41***a* constituting the oil separation mechanism **41**, and the accompanying refrigeration oil is separated. The refrigeration oil separated from the high-pressure refrigerant in the oil separator **41***a* flows into the oil return tube **41***b* constituting the oil separation mechanism **41** wherein it is depressurized by the depressurization mechanism **41***c* provided to the oil return tube **41***b*, and the oil is then returned to the intake tube **2***a* of the compression mechanism **2** and led back into the compression mechanism **2**. Next, having been separated from the refrigeration oil in the oil separation mechanism **41**, the high-pressure refrigerant is passed through the non-return mechanism **42** and the switching mechanism **3** and fed to the usage-side heat exchanger **6** functioning as a refrigerant radiator, and is cooled by heat exchange with water or air as a cooling source (refer to point F in FIGS. **7** and **9** through **11**). The high-pressure refrigerant cooled in the usage-side heat exchanger **6** then flows into the receiver inlet tube **18***a* through the inlet non-return valve **17***b* of the bridge circuit **17**, is depressurized by the first expansion mechanism **5***a* to a pressure near the saturation pressure, and is temporarily retained in the receiver **18** (refer to point I in FIGS. **7** and **11**). The refrigerant retained in the receiver **18** is fed to the receiver outlet tube **18***b* and is depressurized by the second expansion mechanism **5***b* to become a low-pressure gas-liquid two-phase refrigerant, and is then fed through the outlet non-return valve **17***d* of the bridge circuit **17** to the heat source-side heat exchanger **4** functioning as a refrigerant evaporator (refer to point E in FIGS. **7**, and **9** to **11**). The low-pressure gas-liquid two-phase refrigerant fed to the heat source-side heat exchanger **4** is heated by heat exchange with water or air as a heating source, and the refrigerant evaporates as a result (refer to point A in FIGS. **7**, **9** through **11**). The low-pressure refrigerant heated in the heat source-side heat exchanger **4** is then led back into the compression mechanism **2** via the switching mechanism **3**. In this manner the air-warming operation is performed.

In the air-warming operation in which the switching mechanism **3** is in the heating operation state in the air-conditioning apparatus **1** of the present modification, the intercooler on/off valve **12** is closed, and the intercooler bypass on/off valve **11** is opened, thereby placing the intercooler **7** into a state of not functioning as a cooler. Temperature decreases are therefore minimized in the refrigerant discharged from the compression mechanism **2** (refer to points D, D' in FIG. **10**) in comparison to a case in which only the intercooler **7** is provided, or a case in which the intercooler **7** is caused to function as a cooler in the same manner as during the air-cooling operation described above (in this case, the refrigeration cycle is performed in the sequence in FIGS. **9** and **10**: point A→point B1→point C1'→point D'→point F→point E). Therefore, in the air-conditioning apparatus **1**, heat radiation to the exterior can be minimized, temperature decreases can be minimized in the refrigerant supplied to the usage-side heat exchanger **6** functioning as a refrigerant radiator, reduction in heating performance can be minimized in proportion to the difference between the enthalpy difference of points D and F and the enthalpy difference of points D' and F in FIG. **9**, and reduction in operating efficiency can be prevented, in comparison with cases in which only the intercooler **7** is provided or cases in which the intercooler **7** is made to function as a cooler similar to the air-cooling operation described above.

Furthermore, the air-conditioning apparatus **1** of the present modification is configured so that the refrigerant discharged from the first-stage compression element **2***c* is drawn into the second-stage compression element **2***d* via the intercooler bypass tube **9**, and the intercooler **7** and the intake side of the compression mechanism **2** are connected via the first intake return tube **92** during air-warming operation as well in which the switching mechanism **3** is in the heating operation state, the same as at the start of air-cooling operation. It is therefore possible to prevent heat radiation loss to the outside from the intercooler **7** when the switching mechanism **3** is in the heating operation state, and a state can be created in which liquid refrigerant does not readily accumulate in the intercooler **7**. In the air-conditioning apparatus **1** of the present modification, a reduction in heating performance in the usage-side heat exchanger **6** functioning as a refrigerant radiator can thereby be suppressed when the switching mechanism **3** is in the heating operation state, liquid refrigerant can be prevented from accumulating in the intercooler **7** at the start of operation in which the switching mechanism **3** is in the cooling operation state, and the refrigerant discharged from the first-stage compression element **2***c* can be drawn into the second-stage compression element **2***d* via the intercooler **7** without liquid compression occurring in the second-stage compression element **2***d* due to accumulation of liquid refrigerant in the intercooler **7**.

In the present modification, switching between air-cooling operation and air-cooling start control, i.e., switching between the refrigerant non-return state and the refrigerant return state, is accomplished by the on/off states of the on/off valves **11**, **12**, **92***a*. However, an intercooler switching valve

93 may also be provided which is capable of switching between a refrigerant non-return state and a refrigerant return state, instead of the on/off valves **11**, **12**, **92***a*, as in Modification 1 described above.

(5) Modification 3

In Modification 2 described above, the air-conditioning apparatus **1** which performs a two-stage compression refrigeration cycle and is configured to be capable of switching between air-cooling operation and air-warming operation through the use of the switching mechanism **3** is provided with the intercooler **7** for functioning as a cooler for refrigerant discharged from the first-stage compression element **2***c* and drawn into the second-stage compression element **2***d*; the intercooler bypass tube **9** connected to the intermediate refrigerant tube **8** so as to bypass the intercooler **7**; and the first intake return tube **92** for connecting the intercooler **7** and the intake side of the compression mechanism **2** during a state in which the refrigerant discharged from the first-stage compression element **2***c* is drawn into the second-stage compression element **2***d* via the intercooler bypass tube **9**. However, this configuration may be modified so as to perform intermediate pressure injection by a first second-stage injection tube **19** and an economizer heat exchanger **20**.

For example, as shown in FIG. **12**, the refrigerant circuit **210** (refer to FIG. **7**) according to Modification 2 which employs the two-stage compression-type compression mechanism **2** may be modified to create a refrigerant circuit **310** in which the first second-stage injection tube **19** and the economizer heat exchanger **20** are provided.

The first second-stage injection tube **19** has a function for branching off and returning the refrigerant flowing between the heat source-side heat exchanger **4** and the usage-side heat exchanger **6** to the second-stage compression element **2***d* of the compression mechanism **2**. In the present modification, the first second-stage injection tube **19** is provided so as to branch off refrigerant flowing through the receiver inlet tube **18***a* and return the refrigerant to the intake side of the second-stage compression element **2***d*. More specifically, the first second-stage injection tube **19** is provided so as to branch off the refrigerant from a position upstream from the first expansion mechanism **5***a* of the receiver inlet tube **18***a* (i.e., a position between the heat source-side heat exchanger **4** and the first expansion mechanism **5***a* when the switching mechanism **3** is in the cooling operation state) and return the refrigerant to a position downstream from the intercooler **7** of the intermediate refrigerant tube **8**. The first second-stage injection tube **19** is provided with a first second-stage injection valve **19***a* whose opening degree can be controlled. The first second-stage injection valve **19***a* is an electrically driven expansion valve in the present modification.

The economizer heat exchanger **20** is a heat exchanger for carrying out heat exchange between the refrigerant flowing between the heat source-side heat exchanger **4** and the usage-side heat exchanger **6** and the refrigerant that flows through the first second stage injection tube **19** (more specifically, the refrigerant that has been depressurized to near intermediate pressure in the first second-stage injection valve **19***a*). In the present modification, the economizer heat exchanger **20** is provided so as to exchange heat between the refrigerant flowing through the first second-stage injection tube **19** and the refrigerant flowing through a position upstream from the first expansion mechanism **5***a* of the receiver inlet tube **18***a* (i.e., a position between the heat source-side heat exchanger **4** and the first expansion mechanism **5***a* when the switching mechanism **3** is in the cooling operation state), and has flow channels whereby the refrigerant flowing through the first second-stage injection tube **19** and the refrigerant flowing through a position upstream from the first expansion mechanism **5***a* of the receiver inlet tube **18***a* both flow so as to oppose each other. In the present modification, the economizer heat exchanger **20** is provided downstream from the position at which the first second-stage injection tube **19** branches off from the receiver inlet tube **18***a*. Therefore, the refrigerant flowing between the heat source-side heat exchanger **4** and the usage-side heat exchanger **6** is branched off in the receiver inlet tube **18***a* into the first second-stage injection tube **19** before undergoing heat exchange in the economizer heat exchanger **20**, and heat exchange is then conducted in the economizer heat exchanger **20** with the refrigerant flowing through the first second-stage injection tube **19**.

In the present modification, when the switching mechanism **3** is brought to the cooling operation state, the high-pressure refrigerant cooled in the heat source-side heat exchanger **4** can be fed to the usage-side heat exchanger **6** through the inlet non-return valve **17***a* of the bridge circuit **17**, the economizer heat exchanger **20**, the first expansion mechanism **5***a* of the receiver inlet tube **18***a*, the receiver **18**, the second expansion mechanism **5***b* of the receiver outlet tube **18***b*, and the outlet non-return valve **17***c* of the bridge circuit **17**. When the switching mechanism **3** is brought to the heating operation state, the high-pressure refrigerant cooled in the usage-side heat exchanger **6** can be fed to the heat source-side heat exchanger **4** through the inlet non-return valve **17***b* of the bridge circuit **17**, the economizer heat exchanger **20**, the first expansion mechanism **5***a* of the receiver inlet tube **18***a*, the receiver **18**, the second expansion mechanism **5***b* of the receiver outlet tube **18***b*, and the outlet non-return valve **17***d* of the bridge circuit **17**.

Furthermore, in the present modification, the intermediate refrigerant tube **8** or the compression mechanism **2** is provided with an intermediate pressure sensor **54** for detecting the pressure of the refrigerant that flows through the intermediate refrigerant tube **8**. The outlet of the first second stage injection tube **19** side of the economizer heat exchanger **20** is provided with an economizer outlet temperature sensor **55** for detecting the temperature of the refrigerant at the outlet of the first second stage injection tube **19** side of the economizer heat exchanger **20**.

Next, the action of the air-conditioning apparatus **1** of the present modification will be described using FIGS. **12** through **16**. FIG. **13** is a pressure-enthalpy graph representing the refrigeration cycle during the air-cooling operation, FIG. **14** is a temperature-entropy graph representing the refrigeration cycle during the air-cooling operation, FIG. **15** is a pressure-enthalpy graph representing the refrigeration cycle during the air-warming operation, and FIG. **16** is a temperature-entropy graph representing the refrigeration cycle during the air-warming operation. This air-cooling starting control is the same as that of Modification 2 described above and is therefore not described herein. Operational control of the air-cooling operation and air-warming operation (also including the air-cooling start control not described herein) described below is performed by the control unit (not shown) of the embodiment described above. In the following description, the term "high pressure" means a high pressure in the refrigeration cycle (specifically, the pressure at points D, D', E, and H in FIGS. **13** and **14**, and the pressure at points D, D', F, and H in FIGS. **15** and **16**), the term "low pressure" means a low pressure in the refrigeration cycle (specifically, the pressure at points A and F in FIGS. **13** and **14**, and the pressure at points A and E in FIGS. **15** and **16**), and the term "intermediate pressure" means an intermediate pressure in the refrigeration cycle (specifically, the pressure at points B**1**, C**1**, G, J, and K in FIGS. **13** through **16**).

<Air-Cooling Operation>

During the air-cooling operation, the switching mechanism **3** is brought to the cooling operation state shown by the solid lines in FIG. **12**. The opening degrees of the first expansion mechanism **5***a* and the second expansion mechanism **5***b* are also adjusted. Furthermore, the opening degree of the first second-stage injection valve **19***a* is also adjusted. More specifically, in the present embodiment, so-called superheat degree control is performed wherein the opening degree of the first second-stage injection valve **19***a* is adjusted so that a target value is achieved in the degree of superheat of the refrigerant at the outlet in the first second-stage injection tube **19** side of the economizer heat exchanger **20**. In the present modification, the degree of superheat of the refrigerant at the outlet in the first second-stage injection tube **19** side of the economizer heat exchanger **20** is obtained by converting the intermediate pressure detected by the intermediate pressure sensor **54** to a saturation temperature and subtracting this refrigerant saturation temperature value from the refrigerant temperature detected by the economizer outlet temperature sensor **55**. Though not used in the present modification, another possible option is to provide a temperature sensor to the inlet in the first second-stage injection tube **19** side of the economizer heat exchanger **20**, and to obtain the degree of superheat of the refrigerant at the outlet in the first second-stage injection tube **19** side of the economizer heat exchanger **20** by subtracting the refrigerant temperature detected by this temperature sensor from the refrigerant temperature detected by the economizer outlet temperature sensor **55**. Adjustment of the opening degree of the first second-stage injection valve **19***a* is also not limited to being performed by superheat degree control, and the first second-stage injection valve **19***a* may be opened to a predetermined opening degree in accordance with such factors as the flow rate of refrigerant circulated in the refrigerant circuit **10**, for example. Since the switching mechanism **3** is in the cooling operation state, the intercooler on/off valve **12** of the intermediate refrigerant tube **8** is opened, and the intercooler bypass on/off valve **11** of the intercooler bypass tube **9** is closed, thereby creating a state in which the intercooler **7** functions as a cooler. The first intake return on/off valve **92***a* of the first intake return tube **92** is also closed, thereby creating a state in which the intercooler **7** and the intake side of the compression mechanism **2** are not connected (except during air-cooling start control).

When the refrigerant circuit **310** is in this state, low-pressure refrigerant (refer to point A in FIGS. **12** through **14**) is drawn into the compression mechanism **2** through the intake tube **2***a*, and after the refrigerant is first compressed to an intermediate pressure by the compression element **2***c*, the refrigerant is discharged to the intermediate refrigerant tube **8** (refer to point B1 in FIGS. **12** through **14**). The intermediate-pressure refrigerant discharged from the first-stage compression element **2***c* is cooled by heat exchange with water or air as a cooling source in the intercooler **7** (refer to point C1 in FIGS. **12** to **14**). The refrigerant cooled in the intercooler **7** is further cooled (refer to point G in FIGS. **12** to **14**) by being mixed with refrigerant being returned from the first second-stage injection tube **19** to the second stage compression element **2***d* (refer to point K in FIGS. **12** to **14**). Next, having been mixed with the refrigerant returning from the first second-stage injection tube **19** (i.e., intermediate pressure injection is carried out by the economizer heat exchanger **20**), the intermediate-pressure refrigerant is led to and further compressed in the compression element **2***d* connected to the second-stage side of the compression element **2***c*, and the refrigerant is discharged from the compression mechanism **2** to the discharge tube **2***b* (refer to point D in FIGS. **12** through **14**). The high-pressure refrigerant discharged from the compression mechanism **2** is compressed by the two-stage compression action of the compression elements **2***c*, **2***d* to a pressure exceeding a critical pressure (i.e., the critical pressure Pcp at the critical point CP shown in FIG. **13**). The high-pressure refrigerant discharged from the compression mechanism **2** flows into the oil separator **41***a* constituting the oil separation mechanism **41**, and the accompanying refrigeration oil is separated. The refrigeration oil separated from the high-pressure refrigerant in the oil separator **41***a* flows into the oil return tube **41***b* constituting the oil separation mechanism **41** wherein it is depressurized by the depressurization mechanism **41***c* provided to the oil return tube **41***b*, and the oil is then returned to the intake tube **2***a* of the compression mechanism **2** and led back into the compression mechanism **2**. Next, having been separated from the refrigeration oil in the oil separation mechanism **41**, the high-pressure refrigerant is passed through the non-return mechanism **42** and the switching mechanism **3**, and is fed to the heat source-side heat exchanger **4** functioning as a refrigerant radiator. The high-pressure refrigerant fed to the heat source-side heat exchanger **4** is cooled in the heat source-side heat exchanger **4** by heat exchange with water or air as a cooling source (refer to point E in FIGS. **12** through **14**). The high-pressure refrigerant cooled in the heat source-side heat exchanger **4** flows through the inlet non-return valve **17***a* of the bridge circuit **17** into the receiver inlet tube **18***a*, and some of the refrigerant is branched off into the first second-stage injection tube **19**. The refrigerant flowing through the first second-stage injection tube **19** is depressurized to a nearly intermediate pressure in the first second-stage injection valve **19***a* and is then fed to the economizer heat exchanger **20** (refer to point J in FIGS. **12** to **14**). The refrigerant branched off to the first second-stage injection tube **19** then flows into the economizer heat exchanger **20**, where it is cooled by heat exchange with the refrigerant flowing through the first second-stage injection tube **19** (refer to point H in FIGS. **12** to **14**). The refrigerant flowing through the first second-stage injection tube **19** is heat-exchanged with the high-pressure refrigerant cooled in the heat source-side heat exchanger **4** functioning as a radiator, and heated (refer to point K in FIGS. **12** through **14**), and merges with the intermediate-pressure refrigerant discharged from the first-stage compression element **2***c*, as described above. The high-pressure refrigerant cooled in the economizer heat exchanger **20** is depressurized to a nearly saturated pressure by the first expansion mechanism **5***a* and is temporarily retained in the receiver **18** (refer to point I in FIG. **12**). The refrigerant retained in the receiver **18** is fed to the receiver outlet tube **18***b* and is depressurized by the second expansion mechanism **5***b* to become a low-pressure gas-liquid two-phase refrigerant, and is then fed through the outlet non-return valve **17***c* of the bridge circuit **17** to the usage-side heat exchanger **6** functioning as a refrigerant evaporator (refer to point F in FIGS. **12** to **14**). The low-pressure gas-liquid two-phase refrigerant fed to the usage-side heat exchanger **6** is heated by heat exchange with water or air as a heating source, and the refrigerant is evaporated as a result (refer to point A in FIGS. **12** to **14**). The low-pressure refrigerant heated in the usage-side heat exchanger **6** is then led back into the compression mechanism **2** via the switching mechanism **3**. In this manner the air-cooling operation is performed.

In the configuration of the present modification, as in Modification 2 described above, since the intercooler **7** is in a state of functioning as a cooler during the air-cooling operation in which the switching mechanism **3** is brought to the cooling operation state, heat radiation loss in the heat source-side heat exchanger **4** can be reduced in comparison with cases in which no intercooler **7** is provided.

Moreover, in the configuration of the present modification, since the first second-stage injection tube **19** and the economizer heat exchanger **20** are provided so as to branch off refrigerant fed from the heat source-side heat exchanger **4** to the expansion mechanisms **5***a*, **5***b* and return the refrigerant to the second-stage compression element **2***d*, the temperature of refrigerant drawn into the second-stage compression element **2***d* can be kept even lower (refer to points C**1** and G in FIG. **14**) without performing heat radiation to the exterior, such as is done with the intercooler **7**. The temperature of refrigerant discharged from the compression mechanism **2** is thereby kept even lower (refer to points D and D' in FIG. **14**), and operating efficiency can be further improved because heat radiation loss can be further reduced in proportion to the area enclosed by connecting the points C**1**, D', D, and G in FIG. **14**, in comparison with cases in which no first second-stage injection tube **19** is provided.

Moreover, in the present modification as well, since the refrigerant discharged from the first-stage compression element **2***c* is drawn into the second-stage compression element **2***d* through the intercooler bypass tube **9**, and the intercooler **7** and the intake side of the compression mechanism **2** are connected by the first intake return tube **92** at the start of air-cooling operation in which the switching mechanism **3** is in the cooling operation state, even when liquid refrigerant has accumulated in the intercooler **7** prior to the start of operation with the switching mechanism **3** in the cooling operation state, this liquid refrigerant can be drawn out to the outside of the intercooler **7**, the same as in Modification 2 described above. It is thereby possible to prevent a state in which liquid refrigerant has accumulated in the intercooler **7** at the start of operation with the switching mechanism **3** in the cooling operation state, there is no liquid compression in the second-stage compression element **2***d* due to accumulation of the liquid refrigerant in the intercooler **7**, and the reliability of the compression mechanism **2** can be enhanced.

<Air-Warming Operation>

During the air-warming operation, the switching mechanism **3** is brought to the heating operation state shown by the dashed lines in FIG. **12**. The opening degrees of the first expansion mechanism **5***a* and the second expansion mechanism **5***b* are also adjusted. Furthermore, the opening degree of the first second-stage injection valve **19***a* is adjusted in the same manner as the air-cooling operation described above. Since the switching mechanism **3** is set to a heating operation state, the intercooler on/off valve **12** of the intermediate refrigerant tube **8** is closed and the intercooler bypass on/off valve **11** of the intercooler bypass tube **9** is opened, thereby putting the intercooler **7** into a state of not functioning as a cooler. Furthermore, since the switching mechanism **3** is in the heating operation state, the first intake return on/off valve **92***a* of the first intake return tube **92** is opened, thereby causing the intercooler **7** and the intake side of the compression mechanism **2** to be connected.

When the refrigerant circuit **310** is in this state, low-pressure refrigerant (refer to point A in FIG. **12** and FIGS. **15** through **16**) is drawn into the compression mechanism **2** through the intake tube **2***a*, and after the refrigerant is first compressed to an intermediate pressure by the compression element **2***c*, the refrigerant is discharged to the intermediate refrigerant tube **8** (refer to point B**1** in FIG. **12**, FIGS. **15**, and **16**). Unlike the air-cooling operation, the intermediate-pressure refrigerant discharged from the first-stage compression element **2***c* passes through the intercooler bypass tube **9** (refer to point C**1** in FIGS. **12**, **15**, and **16**) without passing through the intercooler **7** (i.e., without being cooled), and the refrigerant is cooled (refer to point G in FIGS. **12**, **15**, and **16**) by being mixed with refrigerant being returned from the first second-stage injection tube **19** to the second-stage compression element **2***d* (refer to point K in FIGS. **12**, **15**, and **16**). Next, having been mixed with the refrigerant returning from the first second-stage injection tube **19**, the intermediate-pressure refrigerant is led to and further compressed in the compression element **2***d* connected to the second-stage side of the compression element **2***c*, and is discharged from the compression mechanism **2** to the discharge tube **2***b* (refer to point D in FIGS. **12**, **15** and **16**). The high-pressure refrigerant discharged from the compression mechanism **2** is compressed by the two-stage compression action of the compression elements **2***c*, **2***d* to a pressure exceeding a critical pressure (i.e., the critical pressure Pcp at the critical point CP shown in FIG. **15**), similar to the air-cooling operation. The high-pressure refrigerant discharged from the compression mechanism **2** flows into the oil separator **41***a* constituting the oil separation mechanism **41**, and the accompanying refrigeration oil is separated. The refrigeration oil separated from the high-pressure refrigerant in the oil separator **41***a* flows into the oil return tube **41***b* constituting the oil separation mechanism **41** wherein it is depressurized by the depressurization mechanism **41***c* provided to the oil return tube **41***b*, and the oil is then returned to the intake tube **2***a* of the compression mechanism **2** and led back into the compression mechanism **2**. Next, having been separated from the refrigeration oil in the oil separation mechanism **41**, the high-pressure refrigerant is passed through the non-return mechanism **42** and the switching mechanism **3** and fed to the usage-side heat exchanger **6** functioning as a refrigerant radiator, and is cooled by heat exchange with water or air as a cooling source (refer to point F in FIGS. **12**, **15**, and **16**). The high-pressure refrigerant cooled in the usage-side heat exchanger **6** flows through the inlet non-return valve **17***b* of the bridge circuit **17** into the receiver inlet tube **18***a*, and some of the refrigerant is branched off into the first second-stage injection tube **19**. The refrigerant flowing through the first second-stage injection tube **19** is depressurized to a nearly intermediate pressure in the first second-stage injection valve **19***a* and is then fed to the economizer heat exchanger **20** (refer to point J in FIGS. **12**, **15**, and **16**). The refrigerant branched off to the first second-stage injection tube **19** then flows into the economizer heat exchanger **20**, where it is cooled by heat exchange with the refrigerant flowing through the first second-stage injection tube **19** (refer to point H in FIGS. **12**, **15**, and **16**). The refrigerant flowing through the first second-stage injection tube **19** is heat-exchanged with the high-pressure refrigerant cooled in the heat source-side heat exchanger **4** functioning as a radiator, and heated (refer to point K in FIGS. **12**, **15** and **16**); and merges with the intermediate-pressure refrigerant discharged from the first-stage compression element **2***c*, as described above. The high-pressure refrigerant cooled in the economizer heat exchanger **20** is depressurized to a nearly saturated pressure by the first expansion mechanism **5***a* and is temporarily retained in the receiver **18** (refer to point I in FIG. **12**). The refrigerant retained in the receiver **18** is fed to the receiver outlet tube **18***b* and is depressurized by the second expansion mechanism **5***b* to become a low-pressure gas-liquid two-phase refrigerant, and is then fed through the outlet non-return valve **17***d* of the bridge circuit **17** to the heat source-side heat exchanger **4** functioning as a refrigerant evaporator (refer to point E in FIGS. **12**, **15**, and **16**). The low-pressure gas-liquid two-phase refrigerant fed to the heat source-side heat exchanger **4** is heated by heat exchange with water or air as a heating source, and the refrigerant evaporates as a result (refer to point A in FIGS. **12**, **15**, and **16**). The low-pressure refrigerant heated in the heat source-side heat exchanger **4** is then led back into the compression mechanism **2** via the switching mechanism **3**. In this manner the air-warming operation is performed.

As in Modification 2 described above, in the air-warming operation in which the switching mechanism **3** is in the heating operation state in the configuration of the present modification, heat radiation to the outside is minimized, reductions in heating performance are suppressed, and reductions in operating efficiency can be prevented in comparison to a case in which only the intercooler **7** is provided, or a case in which the intercooler **7** is caused to function as a cooler in the same manner as during the air-cooling operation described above.

Moreover, in the configuration of the present modification, since the first second-stage injection tube **19** and the economizer heat exchanger **20** are provided so as to branch off refrigerant fed from the heat source-side heat exchanger **4** to the expansion mechanisms **5***a*, **5***b* and return the refrigerant to the second-stage compression element **2***d* in the same manner as the air-cooling operation, the temperature of refrigerant drawn into the second-stage compression element **2***d* can be kept even lower (refer to points B**1** and G in FIG. **16**) without performing heat radiation to the exterior, such as is done with the intercooler **7**. The temperature of refrigerant discharged from the compression mechanism **2** is thereby kept even lower (refer to points D and D' in FIG. **16**), and operating efficiency can be further improved because heat radiation loss can be reduced in proportion to the area enclosed by connecting the points B**1**, D', D, and G in FIG. **16**, in comparison with cases in which no first second-stage injection tube **19** is provided.

Advantages of both the air-cooling operation and the air-warming operation in the configuration of the present modification are that the economizer heat exchanger **20** is a heat exchanger which has flow channels through which refrigerant fed from the heat source-side heat exchanger **4** or usage-side heat exchanger **6** to the expansion mechanisms **5***a*, **5***b* and refrigerant flowing through the first second-stage injection tube **19** both flow so as to oppose each other; therefore, it is possible to reduce the temperature difference between the refrigerant fed to the expansion mechanisms **5***a*, **5***b* from the heat source-side heat exchanger **4** or the usage-side heat exchanger **6** in the economizer heat exchanger **20** and the refrigerant flowing through the first second-stage injection tube **19**, and high heat exchange efficiency can be achieved.

In the present modification as well, the refrigerant discharged from the first-stage compression element **2***c* is drawn into the second-stage compression element **2***d* via the intercooler bypass tube **9**, and the intercooler **7** and the intake side of the compression mechanism **2** are connected via the first intake return tube **92** during air-warming operation as well in which the switching mechanism **3** is in the heating operation state, the same as in Modification 2 described above. It is therefore possible to prevent heat radiation loss to the outside from the intercooler **7** when the switching mechanism **3** is in the heating operation state, and a state can be created in which liquid refrigerant does not readily accumulate in the intercooler **7**. A reduction in heating performance in the usage-side heat exchanger **6** functioning as a refrigerant radiator can thereby be suppressed during air-warming operation in which the switching mechanism **3** is in the heating operation state, liquid refrigerant can be prevented from accumulating in the intercooler **7** at the start of operation in which the switching mechanism **3** is in the cooling operation state, and the refrigerant discharged from the first-stage compression element **2***c* can be drawn into the second-stage compression element **2***d* via the intercooler **7** without liquid compression occurring in the second-stage compression element **2***d* due to accumulation of liquid refrigerant in the intercooler **7**.

In the present modification, switching between air-cooling operation and air-cooling start control, i.e., switching between the refrigerant non-return state and the refrigerant return state, is accomplished by the on/off states of the on/off valves **11**, **12**, **92***a*. However, an intercooler switching valve **93** may also be provided which is capable of switching between a refrigerant non-return state and a refrigerant return state, instead of the on/off valves **11**, **12**, **92***a*, as in Modification 1 described above.

(6) Modification 4

In the refrigerant circuit **310** (refer to FIG. **12**) in Modification 3 described above, in both the air-cooling operation in which the switching mechanism **3** is in the cooling operation state, and the air-warming operation in which the switching mechanism **3** is in the heating operation state, the temperature of the refrigerant discharged from the second-stage compression element **2***d* is reduced, the power consumption of the compression mechanism **2** is reduced, and operating efficiency is enhanced by performing intermediate pressure injection through the use of the economizer heat exchanger **20**, as described above. Since intermediate pressure injection by the economizer heat exchanger **20** can also be used in conditions in which the intermediate pressure of the refrigeration cycle is increased to near critical pressure, a configuration having the single usage-side heat exchanger **6** such as that of the refrigerant circuits **10**, **110**, **210**, **310** (refer to FIGS. **1 6**, **7**, and **12**) in the embodiment and modifications thereof described above is considered to be particularly advantageous in cases in which a refrigerant for operating in a supercritical range is used.

However, it is sometimes the case that a configuration is adopted in which a plurality of usage-side heat exchangers **6** connected to each other in parallel are provided for such purposes as performing air-cooling and/or air-warming in accordance with the air conditioning loads of a plurality of air conditioning spaces, and a usage-side expansion mechanism **5***c* corresponding to each usage-side heat exchanger **6** is provided between each usage-side heat exchanger **6** and the receiver **18** functioning as a gas-liquid separator, in order to control the flow rate of refrigerant to each usage-side heat exchanger **6** and make it possible to obtain the necessary refrigeration load in each usage-side heat exchanger **6**.

For example, though not shown in detail in the drawings, the refrigerant circuit **310** (refer to FIG. **12**) having the bridge circuit **17** according to Modification 3 described above may have a configuration in which a plurality of (two in this case) usage-side heat exchangers **6** connected to each other in parallel are provided, a usage-side expansion mechanism **5***c* corresponding to each usage-side heat exchanger **6** is provided between each usage-side heat exchanger **6** and the receiver **18** (more specifically, the bridge circuit **17**) functioning as a gas-liquid separator (refer to FIG. **17**), the second expansion mechanism **5***b* provided to the receiver outlet tube **18***b* is omitted, and a third expansion mechanism for depressurizing the refrigerant to the low pressure of the refrigeration cycle during air-warming operation is provided instead of the outlet non-return valve **17***d* of the bridge circuit **17**.

As in Modification 2 described above, intermediate pressure injection by the economizer heat exchanger **20** is advantageous also in the above-described configuration in conditions in which the difference in pressure from the high pressure of the refrigeration cycle to near the intermediate pressure of the refrigeration cycle can be utilized without significant depressurization other than by the first expansion mechanism **5***a* as a heat source-side expansion mechanism after the refrigerant has been cooled in the heat source-side heat exchanger **4** functioning as a radiator, as in the case of air-cooling operation in which the switching mechanism **3** is in the cooling operation state.

However, in conditions in which the usage-side expansion mechanisms **5***c* are controlling the flow rate of refrigerant flowing through the usage-side heat exchangers **6** as radiators so that the necessary refrigeration load is obtained in the usage-side heat exchangers **6** as radiators, and the flow rate of refrigerant passing through the usage-side heat exchangers **6** as radiators is roughly determined by refrigerant depressurization by control of the opening degree of the usage-side expansion mechanisms **5***c* provided downstream from the usage-side heat exchangers **6** as radiators and upstream from the economizer heat exchanger **20**, such as during air-warming operation in which the switching mechanism **3** is in the heating operation state, the degree to which the refrigerant is depressurized by controlling the opening degree of the usage-side expansion mechanisms **5***c* varies according to not only the flow rate of refrigerant flowing through the usage-side heat exchangers **6** as radiators, but also to the state of flow rate distribution among the plurality of usage-side heat exchangers **6** as radiators, a state occurs in which the degree of depressurization varies significantly among the plurality of usage-side expansion mechanisms **5***c*, and the degree of depressurization in each usage-side expansion mechanism **5***c* is relatively large. There is accordingly a risk of reduced pressure of the refrigerant in the inlet of the economizer heat exchanger **20**, in this case too little heat is exchanged in the economizer heat exchanger **20** (i.e., the flow rate of refrigerant flowing through the first second-stage injection tube **19**), and the heat is difficult to utilize. Particularly in a case in which such an air-conditioning apparatus **1** is configured as a separate-type air conditioning apparatus in which a heat source unit including primarily the compression mechanism **2**, the heat source-side heat exchanger **4**, and the receiver **18**, and a usage unit which includes primarily the usage-side heat exchanger **6** are connected by connecting piping, depending on the placement of the usage unit and the heat source unit, since the connecting piping can become extremely long, the effects of the resultant pressure drop combine to further reduce the pressure of the refrigerant in the inlet of the economizer heat exchanger **20**. In cases in which there is a risk of reduced pressure of the refrigerant in the inlet of the economizer heat exchanger **20**, intermediate pressure injection by a gas-liquid separator is advantageous in that it can be used even in conditions in which the difference in pressure between the gas-liquid separator pressure and the intermediate pressure (here, the pressure of the refrigerant flowing through the intermediate refrigerant tube **8**) of the refrigeration cycle is small when the gas-liquid separator pressure is lower than the critical pressure.

Therefore, in the present modification as shown in FIG. **17**, in order to cause the receiver **18** to function as a gas-liquid separator and enable intermediate pressure injection, a second second-stage injection tube **18***c* is connected to the receiver **18**, and a refrigerant circuit **410** is configured so that intermediate pressure injection by the economizer heat exchanger **20** can be performed during air-cooling operation, and intermediate pressure injection by the receiver **18** as a gas-liquid separator can be performed during air-warming operation.

The second second-stage injection tube **18***c* is a refrigerant tube capable of intermediate pressure injection for withdrawing refrigerant from the receiver **18** and returning the refrigerant to the second-stage compression element **2***d* of the compression mechanism **2**, and in the present modification, the second second-stage injection tube **18***c* is provided so as to connect the upper part of the receiver **18** with the intermediate refrigerant tube **8** (i.e., the intake side of the second-stage compression element **2***d* of the compression mechanism **2**). The second second-stage injection tube **18***c* is provided with a second second-stage injection on/off valve **18***d* and a second second-stage injection non-return mechanism **18***e*. The second second-stage injection on/off valve **18***d* is a valve capable of opening and closing, and is an electromagnetic valve in the present modification. The second second-stage injection non-return mechanism **18***e* is a mechanism for allowing refrigerant to flow from the receiver **18** to the second-stage compression element **2***d* and blocking the flow of refrigerant from the second-stage compression element **2***d* to the receiver **18**, and is a non-return valve in the present embodiment. The portions of the second second-stage injection tube **18***c* and the second intake return tube **18***f* toward the receiver **18** are integrated. The portions of the second second-stage injection tube **18***c* and the first second-stage injection tube **19** toward the intermediate refrigerant tube **8** are also integrated. The usage-side expansion mechanism **5***c* is an electrically driven expansion valve in the present modification. Since the present modification is configured so that the first second-stage injection tube **19** and the economizer heat exchanger **20** are used during air-cooling operation and the second second-stage injection tube **18***c* is used during air-warming operation, as described above, there is no need for the direction of flow of the refrigerant to the economizer heat exchanger **20** to be constant irrespective of air-cooling operation or air-warming operation. The bridge circuit **17** is therefore omitted, and the structure of the refrigerant circuit **410** is simplified.

Next, the action of the air-conditioning apparatus **1** will be described using FIGS. **17**, **13**, **14**, **18**, and **19**. FIG. **18** is a pressure-enthalpy graph representing the refrigeration cycle during the air-warming operation, and FIG. **19** is a temperature-entropy graph representing the refrigeration cycle during the air-warming operation. Here, the air-cooling start control is the same as that of Modification 2 described above and is therefore not described herein. The refrigeration cycle during air-cooling operation in the present modification is described using FIGS. **13** and **14**. Operation controls during the following air-cooling operation and air-warming operation are performed by the controller (not shown) described in the embodiment above. In the following description, the term "high pressure" means a high pressure in the refrigeration cycle (specifically, the pressure at points D, D', E, and H in FIGS. **13** and **14**, and the pressure at points D, D', and F in FIGS. **18** and **19**), the term "low pressure" means a low pressure in the refrigeration cycle (specifically, the pressure at points A and F in FIGS. **13** and **14**, and the pressure at points A and E in FIGS. **18** and **19**), and the term "intermediate pressure" means an intermediate pressure in the refrigeration cycle (specifically, the pressure at points B**1**, C**1**, G, J, and K in FIGS. **13** and **14**, and the pressure at points B**1**, C**1**, G, I, L, and M in FIGS. **18** and **19**).

<Air-Cooling Operation>

During the air-cooling operation, the switching mechanism **3** is brought to the cooling operation state shown by the solid lines in FIG. **17**. The opening degrees of the usage-side expansion mechanisms **5***c* and the first expansion mechanism **5***a* as the heat source-side expansion mechanism are adjusted. Since the switching mechanism **3** is in the cooling operation state, the intercooler on/off valve **12** of the intermediate refrigerant tube **8** is opened, and the intercooler bypass on/off valve **11** of the intercooler bypass tube **9** is closed, whereby the intercooler **7** is caused to function as a cooler. The first intake return on/off valve **92***a* of the first intake return tube **92** is also closed, thereby bringing about a state in which the intercooler **7** and the intake side of the compression mechanism **2** are not connected (except during the air-cooling start control). When the switching mechanism **3** is in the cooling operation state, intermediate pressure injection by the receiver **18** as a gas-liquid separator is not performed, and intermediate pressure injection by the economizer heat exchanger **20** is performed to return the refrigerant heated in the economizer heat exchanger **20** to the second-stage compression element **2***d* through the first second-stage injection tube **19**. More specifically, the second second-stage injection on/off valve **18***d* is closed, and the opening degree of the first second-stage injection valve **19***a* is adjusted in the same manner as in Modification 3 described above.

When the refrigerant circuit **410** is in this state, low-pressure refrigerant (refer to point A in FIG. **17** and FIGS. **13** through **14**) is drawn into the compression mechanism **2** through the intake tube **2***a*, and after the refrigerant is first compressed to an intermediate pressure by the compression element **2***c*, the refrigerant is discharged to the intermediate refrigerant tube **8** (refer to point B**1** in FIG. **17**, FIGS. **13**, and **14**). The intermediate-pressure refrigerant discharged from the first-stage compression element **2***c* is cooled by heat exchange with water or air as a cooling source in the intercooler **7** (refer to point C**1** in FIGS. **17**, **13**, and **14**). The refrigerant cooled in the intercooler **7** is further cooled (refer to point G in FIGS. **17**, **13**, and **14**) by being mixed with refrigerant being returned from the first second-stage injection tube **19** to the second-stage compression element **2***d* (refer to point K in FIGS. **17**, **13**, and **14**). Next, having been mixed with the refrigerant returning from the first second-stage injection tube **19** (i.e., intermediate pressure injection is carried out by the economizer heat exchanger **20**), the intermediate-pressure refrigerant is led to and further compressed in the compression element **2***d* connected to the second-stage side of the compression element **2***c*, and the refrigerant is discharged from the compression mechanism **2** to the discharge tube **2***b* (refer to point D in FIGS. **17**, **13**, and **14**). The high-pressure refrigerant discharged from the compression mechanism **2** is compressed by the two-stage compression action of the compression elements **2***c*, **2***d* to a pressure exceeding a critical pressure (i.e., the critical pressure Pcp at the critical point CP shown in FIG. **13**). The high-pressure refrigerant discharged from the compression mechanism **2** is fed via the switching mechanism **3** to the heat source-side heat exchanger **4** functioning as a refrigerant radiator, and the refrigerant is cooled by heat exchange with water or air as a cooling source (refer to point E in FIGS. **17**, **13**, and **14**). A portion of the high-pressure refrigerant cooled in the heat source-side heat exchanger **4** functioning as a radiator is branched off into the first second-stage injection tube **19**. The refrigerant flowing through the first second-stage injection tube **19** is depressurized to a nearly intermediate pressure in the first second-stage injection valve **19***a* and is then fed to the economizer heat exchanger **20** (refer to point J in FIGS. **17**, **13**, and **14**). The refrigerant branched off to the first second-stage injection tube **19** then flows into the economizer heat exchanger **20**, where it is cooled by heat exchange with the refrigerant flowing through the first second-stage injection tube **19** (refer to point H in FIGS. **17**, **13**, and **14**). The refrigerant flowing through the first second-stage injection tube **19** is heat-exchanged with the high-pressure refrigerant cooled in the heat source-side heat exchanger **4** functioning as a radiator, and heated (refer to point K in FIGS. **17**, **13**, and **14**), and merges with the intermediate-pressure refrigerant discharged from the first-stage compression element **2***c*, as described above. The high-pressure refrigerant cooled in the economizer heat exchanger **20** is depressurized to a nearly saturated pressure by the first expansion mechanism **5***a* and is temporarily retained in the receiver **18** (refer to point I in FIGS. **17**, **13**, and **14**). The refrigerant retained in the receiver **18** is fed to the usage-side expansion mechanism **5***c* and depressurized by the usage-side expansion mechanisms **5***c* to become a low-pressure gas-liquid two-phase refrigerant, which is fed to the usage-side heat exchanger **6** functioning as a refrigerant evaporator (refer to point F in FIGS. **17**, **13**, and **14**). The low-pressure gas-liquid two-phase refrigerant fed to the usage-side heat exchanger **6** that functions as an evaporator is heated by heat exchange with water or air as a heating source, and the refrigerant is evaporated as a result (refer to point A in FIGS. **17**, **13**, and **14**). The low-pressure refrigerant heated and evaporated in the usage-side heat exchanger **6** that functions as an evaporator is then led back into the compression mechanism **2** via the switching mechanism **3**. In this manner the air-cooling operation is performed.

<Air-Warming Operation>

During the air-warming operation, the switching mechanism **3** is brought to the heating operation state shown by the dashed lines in FIG. **17**. The opening degrees of the usage-side expansion mechanisms **5***c* and the first expansion mechanism **5***a* functioning as the heat source-side expansion mechanism are adjusted. Since the switching mechanism **3** is set to a heating operation state, the intercooler on/off valve **12** of the intermediate refrigerant tube **8** is closed and the intercooler bypass on/off valve **11** of the intercooler bypass tube **9** is opened, thereby putting the intercooler **7** into a state of not functioning as a cooler. Furthermore, since the switching mechanism **3** is in the heating operation state, the first intake return on/off valve **92***a* of the first intake return tube **92** is opened, thereby causing the intercooler **7** and the intake side of the compression mechanism **2** to be connected. When the switching mechanism **3** is in the heating operation state, intermediate pressure injection by the economizer heat exchanger **20** is not performed, and intermediate pressure injection by the receiver **18** is performed to return the refrigerant from the receiver **18** functioning as a gas-liquid separator to the second-stage compression element **2***d* through the second second-stage injection tube **18***c*. More specifically, the second second-stage injection on/off valve **18***d* is open, and the first second-stage injection valve **19***a* is fully closed.

When the refrigerant circuit **410** is in this state, low-pressure refrigerant (refer to point A in FIGS. **17** through **19**) is drawn into the compression mechanism **2** through the intake tube **2***a*, and after the refrigerant is first compressed to an intermediate pressure by the compression element **2***c*, the refrigerant is discharged to the intermediate refrigerant tube **8** (refer to point B**1** in FIGS. **17** through **19**). Unlike the air-cooling operation, the intermediate-pressure refrigerant discharged from the first-stage compression element **2***c* passes through the intercooler bypass tube **9** (refer to point C**1** in FIGS. **17** through **19**) without passing through the intercooler **7** (i.e., without being cooled), and the refrigerant is cooled (refer to point G in FIGS. **17** through **19**) by being mixed with refrigerant being returned from the receiver **18** via the second second-stage injection tube **18***c* to the second-stage compression element **2***d* (refer to point M in FIGS. **17** through **19**). Next, having been mixed with the refrigerant returning from the second second-stage injection tube **18***c* (i.e., intermediate pressure injection is carried out by the receiver **18** which acts as a gas-liquid separator), the intermediate-pressure refrigerant is led to and further compressed in the compression element **2***d* connected to the second-stage side of the compression element **2**c, and the refrigerant is discharged from the compression mechanism **2** to the discharge tube **2**b (refer to point D in FIGS. **17** through **19**). The high-pressure refrigerant discharged from the compression mechanism **2** is compressed by the two-stage compression action of the compression elements **2**c, **2**d to a pressure exceeding a critical pressure (i.e., the critical pressure Pcp at the critical point CP shown in FIG. **18**), similar to the air-cooling operation. The high-pressure refrigerant discharged from the compression mechanism **2** is fed via the switching mechanism **3** to the usage-side heat exchanger **6** functioning as a refrigerant radiator, and the refrigerant is cooled by heat exchange with water or air as a cooling source (refer to point F in FIGS. **17** to **19**). The high-pressure refrigerant cooled in the usage-side heat exchanger **6** functioning as a radiator is depressurized to near the intermediate pressure by the usage-side expansion mechanisms **5**c, and is then temporarily retained in the receiver **18** and separated into gas and liquid (refer to points I, L, and M in FIGS. **17** through **19**). The gas refrigerant separated in the receiver **18** is withdrawn from the upper part of the receiver **18** by the second second-stage injection tube **18**c, and merges with the intermediate-pressure refrigerant discharged from the first-stage compression element **2**c, as described above. The liquid refrigerant retained in the receiver **18** is depressurized by the first expansion mechanism **5**a to become a low-pressure gas-liquid two-phase refrigerant, which is fed to the heat source-side heat exchanger **4** functioning as a refrigerant evaporator (refer to point E in FIGS. **17** through **19**). The low-pressure gas-liquid two-phase refrigerant fed to the heat source-side heat exchanger **4** that functions as an evaporator is heated by heat exchange with water or air as a heating source, and the refrigerant is evaporated as a result (refer to point A in FIGS. **17**, to **19**). The low-pressure refrigerant heated and evaporated in the heat source-side heat exchanger **4** that functions as an evaporator is then led back into the compression mechanism **2** via the switching mechanism **3**. In this manner the air-warming operation is performed.

The configuration of the present modification differs from Modification 3 in that intermediate pressure injection by the receiver **18** as a gas-liquid separator is performed instead of intermediate pressure injection by the economizer heat exchanger **20** during the air-warming operation, but the present modification otherwise produces the same operational effects as Modification 3.

In the present modification, switching between air-cooling operation and air-cooling start control, i.e., switching between the refrigerant non-return state and the refrigerant return state, is accomplished by the on/off states of the on/off valves **11**, **12**, **92**a. However, an intercooler switching valve **93** may also be provided which is capable of switching between a refrigerant non-return state and a refrigerant return state, instead of the on/off valves **11**, **12**, **92**a, as in Modification 1 described above.

(7) Modification 5

In the refrigerant circuit **410** (refer to FIG. **17**) in Modification 4 described above, a configuration is adopted in which the plurality of usage-side heat exchangers **6** connected to each other in parallel are provided for such purposes as performing air-cooling and/or air-warming in accordance with the air conditioning loads of a plurality of air conditioning spaces, and the usage-side expansion mechanism **5**c corresponding to each usage-side heat exchanger **6** is provided between each usage-side heat exchanger **6** and the receiver **18**, in order to control the flow rate of refrigerant to each usage-side heat exchanger **6** and make it possible to obtain the necessary refrigeration load in each usage-side heat exchanger **6**. In such a configuration, refrigerant depressurized by the first expansion mechanism **5**a to near the saturation pressure and temporarily retained in the receiver **18** (refer to point I in FIG. **17**) is distributed to each usage-side expansion mechanism **5**c during the air-cooling operation, but when the refrigerant fed from the receiver **18** to each usage-side expansion mechanism **5**c is in a gas-liquid two-phase state, there is a risk of drifting during distribution to each usage-side expansion mechanism **5**c. The refrigerant fed from the receiver **18** to each usage-side expansion mechanism **5**c is therefore preferably brought to as much a subcooled state as possible.

The refrigerant circuit **410** in Modification 4 described above is therefore configured in the present modification as a refrigerant circuit **510** in which a subcooling heat exchanger **96** and a third intake return tube **95** are provided between the receiver **18** and the usage-side expansion mechanisms **5**c, as shown in FIG. **20**.

The subcooling heat exchanger **96** is a heat exchanger for cooling the refrigerant fed from the receiver **18** to the usage-side expansion mechanisms **5**c. More specifically, the subcooling heat exchanger **96** is a heat exchanger for carrying out heat exchange with the refrigerant flowing through the third intake return tube **95** for branching off a portion of the refrigerant fed from the receiver **18** to the usage-side expansion mechanisms **5**c and returning the refrigerant to the intake side of the compression mechanism **2** (i.e., the intake tube **2**a between the compression mechanism **2** and the usage-side heat exchanger **6** functioning as an evaporator) during air-cooling operation, and the subcooling heat exchanger **96** has flow channels through which both refrigerants flow so as to oppose each other. The third intake return tube **95** is a refrigerant tube for branching off the refrigerant fed to the expansion mechanism **5** from the heat source-side heat exchanger **4** functioning as a radiator and returning the refrigerant to the intake side of the compression mechanism **2** (i.e., the intake tube **2**a). The third intake return tube **95** is provided with a third intake return valve **95**a whose opening degree can be controlled, and heat exchange between the refrigerant fed from the receiver **18** to the usage-side expansion mechanisms **5**c and the refrigerant flowing through the third intake return tube **95** after being depressurized to near the low pressure in the third intake return valve **95**a is carried out in the subcooling heat exchanger **96**. The third intake return valve **95**a is an electromagnetic valve in the present modification. The intake tube **2**a or the compression mechanism **2** is also provided with an intake pressure sensor **60** for detecting the pressure of the refrigerant flowing through the intake side of the compression mechanism **2**. A subcooling heat exchanger outlet temperature sensor **59** for detecting the temperature of the refrigerant in the outlet of the subcooling heat exchanger **96** on the side of the third intake return tube **95** is provided to the outlet of the subcooling heat exchanger **96** on the side of the third intake return tube **95**.

Next, the action of the air-conditioning apparatus **1** in the present modification will be described using FIGS. **20** to **22**, **18**, and **19**. FIG. **21** is a pressure-enthalpy graph representing the refrigeration cycle during the air-cooling operation, and FIG. **22** is a temperature-entropy graph representing the refrigeration cycle during the air-cooling operation. This air-cooling start control is the same as that of Modification 2 described above and is therefore not described herein. The refrigeration cycle during air-warming operation in the present modification is described using FIGS. **18** and **19**. Operation controls during the following air-cooling operation and air-warming operation are performed by the controller (not shown) described in the embodiment above. In the following description, the term "high pressure" means a high pressure in the refrigeration cycle (specifically, the pressure at points D, E, I, and R in FIGS. **21** and **22**, and the pressure at points D, D', and F in FIGS. **18** and **19**), the term "low pressure" means a low pressure in the refrigeration cycle (specifically, the pressure at points A, F, F, S', and U in FIGS. **21** and **22**, and the pressure at points A and E in FIGS. **18** and **19**), and the term "intermediate pressure" means an intermediate pressure in the refrigeration cycle (specifically, the pressure at points B**1**, C**1**, G, J, and K in FIGS. **21** and **22**, and the pressure at points B**1**, C**1**, G, I, L, and M in FIGS. **18** and **19**).

<Air-Cooling Operation>

During the air-cooling operation, the switching mechanism **3** is brought to the cooling operation state shown by the solid lines in FIG. **20**. The opening degrees of the usage-side expansion mechanisms **5***c* and the first expansion mechanism **5***a* as the heat source-side expansion mechanism are adjusted. Since the switching mechanism **3** is in the cooling operation state, the intercooler on/off valve **12** of the intermediate refrigerant tube **8** is opened, and the intercooler bypass on/off valve **11** of the intercooler bypass tube **9** is closed, whereby the intercooler **7** is caused to function as a cooler. The first intake return on/off valve **92***a* of the first intake return tube **92** is also closed, thereby bringing about a state in which the intercooler **7** and the intake side of the compression mechanism **2** are not connected (except during the air-cooling start control). When the switching mechanism **3** is in the cooling operation state, intermediate pressure injection by the receiver **18** as a gas-liquid separator is not performed, and intermediate pressure injection by the economizer heat exchanger **20** is performed to return the refrigerant heated in the economizer heat exchanger **20** to the second-stage compression element **2***d* through the first second-stage injection tube **19**. More specifically, the second second-stage injection on/off valve **18***d* is closed, and the opening degree of the first second-stage injection valve **19***a* is adjusted in the same manner as in Modification 3 described above. Since the subcooling heat exchanger **96** is used when the switching mechanism **3** is in the cooling operation state, the opening degree of the third intake return valve **95***a* is also adjusted. More specifically, in the present modification, so-called superheat degree control is performed wherein the opening degree of the third intake return valve **95***a* is adjusted so that a target value is achieved in the degree of superheat of the refrigerant at the outlet in the third intake return tube **95** side of the subcooling heat exchanger **96**. In the present modification, the degree of superheat of the refrigerant at the outlet in the third intake return tube **95** side of the subcooling heat exchanger **96** is obtained by converting the low pressure detected by the intake pressure sensor **60** to a saturation temperature and subtracting this refrigerant saturation temperature value from the refrigerant temperature detected by the subcooling heat exchanger outlet temperature sensor **59**. Though not used in the present modification, another possible option is to provide a temperature sensor to the inlet in the third intake return tube **95** side of the subcooling heat exchanger **96**, and to obtain the degree of superheat of the refrigerant at the outlet in the third intake return tube **95** side of the subcooling heat exchanger **96** by subtracting the refrigerant temperature detected by this temperature sensor from the refrigerant temperature detected by the subcooling heat exchanger outlet temperature sensor **59**. The opening degree of the third intake return valve **95***a* is not limited to being adjusted by superheat degree control; the third intake return valve **95***a* may also be opened to a predetermined opening degree in accordance with such factors as the circulation rate of refrigerant in the refrigerant circuit **510**, for example.

When the refrigerant circuit **510** is in this state, low-pressure refrigerant (refer to point A in FIGS. **20** through **22**) is drawn into the compression mechanism **2** through the intake tube **2***a*, and after the refrigerant is first compressed to an intermediate pressure by the compression element **2***c*, the refrigerant is discharged to the intermediate refrigerant tube **8** (refer to point B**1** in FIGS. **20** through **22**). The intermediate-pressure refrigerant discharged from the first-stage compression element **2***c* is cooled by heat exchange with water or air as a cooling source in the intercooler **7** (refer to point C**1** in FIGS. **20** to **22**). The refrigerant cooled in the intercooler **7** is further cooled (refer to point G in FIGS. **20** to **22**) by being mixed with refrigerant being returned from the first second-stage injection tube **19** to the second-stage compression element **2***d* (refer to point K in FIGS. **20** to **22**). Next, having been mixed with the refrigerant returning from the first second-stage injection tube **19** (i.e., intermediate pressure injection is carried out by the economizer heat exchanger **20**), the intermediate-pressure refrigerant is led to and further compressed in the compression element **2***d* connected to the second-stage side of the compression element **2***c*, and the refrigerant is discharged from the compression mechanism **2** to the discharge tube **2***b* (refer to point D in FIGS. **20** through **22**). The high-pressure refrigerant discharged from the compression mechanism **2** is compressed by the two-stage compression action of the compression elements **2***c*, **2***d* to a pressure exceeding a critical pressure (i.e., the critical pressure Pcp at the critical point CP shown in FIG. **21**). The high-pressure refrigerant discharged from the compression mechanism **2** is fed via the switching mechanism **3** to the heat source-side heat exchanger **4** functioning as a refrigerant radiator, and the refrigerant is cooled by heat exchange with water or air as a cooling source (refer to point E in FIGS. **20** to **22**). A portion of the high-pressure refrigerant cooled in the heat source-side heat exchanger **4** functioning as a radiator is branched off into the first second-stage injection tube **19**. The refrigerant flowing through the first second-stage injection tube **19** is depressurized to a nearly intermediate pressure in the first second-stage injection valve **19***a* and is then fed to the economizer heat exchanger **20** (refer to point J in FIGS. **20** to **22**). The refrigerant branched off to the first second-stage injection tube **19** then flows into the economizer heat exchanger **20**, where it is cooled by heat exchange with the refrigerant flowing through the first second-stage injection tube **19** (refer to point H in FIGS. **20** to **22**). The refrigerant flowing through the first second-stage injection tube **19** is heat-exchanged with the high-pressure refrigerant cooled in the heat source-side heat exchanger **4** functioning as a radiator, and heated (refer to point K in FIGS. **20** through **22**), and merges with the intermediate-pressure refrigerant discharged from the first-stage compression element **2***c*, as described above. The high-pressure refrigerant cooled in the economizer heat exchanger **20** is depressurized to a nearly saturated pressure by the first expansion mechanism **5***a* and is temporarily retained in the receiver **18** (refer to point I in FIGS. **20** to **22**). A portion of the refrigerant retained in the receiver **18** is then branched off into the third intake return tube **95**. The refrigerant flowing through the third intake return tube **95** is depressurized to a nearly low pressure in the third intake return valve **95***a* and is then fed to the subcooling heat exchanger **96** (refer to point S in FIGS. **20** to **22**). The refrigerant branched off to the third intake return tube **95** then flows into the subcooling heat exchanger **96**, where it is further cooled by heat exchange with the refrigerant flowing through the third intake return tube **95** (refer to point R in FIGS. **20** to **22**). The refrigerant flowing through the third intake return tube **95** is heat-exchanged with the high-pressure refrigerant cooled in the economizer heat exchanger **20**, and heated (refer to point U in FIGS. **20** through **22**), and merges with the refrigerant flowing through the intake side of the compression mechanism **2** (here, the intake tube **2***a*). This refrigerant cooled in the subcooling heat exchanger **96** is fed to the usage-side expansion mechanisms **5***c* and depressurized by the usage-side expansion mechanisms **5***c* to become a low-pressure gas-liquid two-phase refrigerant, which is fed to the usage-side heat exchanger **6** functioning as a refrigerant evaporator (refer to point F in FIGS. **20** through **22**). The low-pressure gas-liquid two-phase refrigerant fed to the usage-side heat exchanger **6** that functions as an evaporator is heated by heat exchange with water or air as a heating source, and the refrigerant is evaporated as a result (refer to point A in FIGS. **20**, to **22**). The low-pressure refrigerant heated and evaporated in the usage-side heat exchanger **6** that functions as an evaporator is then led back into the compression mechanism **2** via the switching mechanism **3**. In this manner the air-cooling operation is performed.

<Air-Warming Operation>

During the air-warming operation, the switching mechanism **3** is brought to the heating operation state shown by the dashed lines in FIG. **20**. The opening degrees of the usage-side expansion mechanisms **5***c* and the first expansion mechanism **5***a* as the heat source-side expansion mechanism are adjusted. Since the switching mechanism **3** is set to a heating operation state, the intercooler on/off valve **12** of the intermediate refrigerant tube **8** is closed and the intercooler bypass on/off valve **11** of the intercooler bypass tube **9** is opened, thereby putting the intercooler **7** into a state of not functioning as a cooler. Furthermore, since the switching mechanism **3** is in the heating operation state, the first intake return on/off valve **92***a* of the first intake return tube **92** is opened, thereby causing the intercooler **7** and the intake side of the compression mechanism **2** to be connected. When the switching mechanism **3** is in the heating operation state, intermediate pressure injection by the economizer heat exchanger **20** is not performed, and intermediate pressure injection by the receiver **18** is performed to return the refrigerant from the receiver **18** functioning as a gas-liquid separator to the second-stage compression element **2***d* through the second second-stage injection tube **18***c*. More specifically, the second second-stage injection on/off valve **18***d* is open, and the first second-stage injection valve **19***a* is fully closed. Since the subcooling heat exchanger **96** is not used when the switching mechanism **3** is in the heating operation state, the third intake return valve **95***a* is also fully closed.

When the refrigerant circuit **510** is in this state, low-pressure refrigerant (refer to point A in FIG. **20** and FIGS. **18** through **19**) is drawn into the compression mechanism **2** through the intake tube **2***a*, and after the refrigerant is first compressed to an intermediate pressure by the compression element **2***c*, the refrigerant is discharged to the intermediate refrigerant tube **8** (refer to point B**1** in FIG. **20**, FIGS. **18**, and **19**). Unlike the air-cooling operation, the intermediate-pressure refrigerant discharged from the first-stage compression element **2***c* passes through the intercooler bypass tube **9** (refer to point C**1** in FIGS. **20**, **18**, and **19**) without passing through the intercooler **7** (i.e., without being cooled), and the refrigerant is cooled (refer to point G in FIGS. **20**, **18**, and **19**) by being mixed with refrigerant being returned from the receiver **18** via the second second-stage injection tube **18***c* to the second-stage compression element **2***d* (refer to point M in FIGS. **20**, **18**, and **19**). Next, having been mixed with the refrigerant returning from the second second-stage injection tube **18***c* (i.e., intermediate pressure injection is carried out by the receiver **18** which acts as a gas-liquid separator), the intermediate-pressure refrigerant is led to and further compressed in the compression element **2***d* connected to the second-stage side of the compression element **2***c*, and the refrigerant is discharged from the compression mechanism **2** to the discharge tube **2***b* (refer to point D in FIGS. **20**, **18**, and **19**). The high-pressure refrigerant discharged from the compression mechanism **2** is compressed by the two-stage compression action of the compression elements **2***c*, **2***d* to a pressure exceeding a critical pressure (i.e., the critical pressure Pcp at the critical point CP shown in FIG. **18**), similar to the air-cooling operation. The high-pressure refrigerant discharged from the compression mechanism **2** is fed via the switching mechanism **3** to the usage-side heat exchanger **6** functioning as a refrigerant radiator, and the refrigerant is cooled by heat exchange with water or air as a cooling source (refer to point F in FIGS. **20**, **18**, and **19**). The high-pressure refrigerant cooled in the usage-side heat exchanger **6** functioning as a radiator is depressurized to near the intermediate pressure by the usage-side expansion mechanisms **5***c*, and is then temporarily retained in the receiver **18** and separated into gas and liquid (refer to points I, L, and M in FIGS. **20**, **18**, and **19**). The gas refrigerant separated in the receiver **18** is withdrawn from the upper part of the receiver **18** by the second second-stage injection tube **18***c*, and merges with the intermediate-pressure refrigerant discharged from the first-stage compression element **2***c*, as described above. The liquid refrigerant retained in the receiver **18** is depressurized by the first expansion mechanism **5***a* to become a low-pressure gas-liquid two-phase refrigerant, which is fed to the heat source-side heat exchanger **4** functioning as a refrigerant evaporator (refer to point E in FIGS. **20**, **18**, and **19**). The low-pressure gas-liquid two-phase refrigerant fed to the heat source-side heat exchanger **4** that functions as an evaporator is heated by heat exchange with water or air as a heating source, and the refrigerant is evaporated as a result (refer to point A in FIGS. **20**, **18**, and **19**). The low-pressure refrigerant heated and evaporated in the heat source-side heat exchanger **4** that functions as an evaporator is then led back into the compression mechanism **2** via the switching mechanism **3**. In this manner the air-warming operation is performed.

The same operational effects are obtained in the configuration of the present modification as in Modification 4 described above, and since the refrigerant fed to the usage-side expansion mechanisms **5***c* from the receiver **18** during air-cooling operation (refer to point I in FIGS. **20** through **22**) can be cooled to the subcooled state by the subcooling heat exchanger **96** (refer to points I and R in FIGS. **21** and **22**), the risk of drift during distribution to the usage-side expansion mechanisms **5***c* can be reduced.

In the present modification, switching between air-cooling operation and air-cooling start control, i.e., switching between the refrigerant non-return state and the refrigerant return state, is accomplished by the on/off states of the on/off valves **11**, **12**, **92***a*. However, an intercooler switching valve **93** may also be provided which is capable of switching between a refrigerant non-return state and a refrigerant return state, instead of the on/off valves **11**, **12**, **92***a*, as in Modification 1 described above.

(8) Modification 6

In the embodiment and modifications thereof described above, the two-stage compression type compression mechanism **2**, whereby the refrigerant discharged from a first-stage compression element of two compression elements **2***c*, **2***d* is sequentially compressed in a second-stage compression element, is configured by the single compressor **21** having a single-shaft, two-stage compression structure. However, a multi-stage compression mechanism having more than two compression stages, such as a three-stage compression mechanism or the like, may also be used, and a multi-stage compression mechanism may be configured by connecting, in series, a plurality of compressors having a single compression element and/or compressors having a plurality of compression elements. In cases in which the capability of the compression mechanism must be increased, such as when numerous usage-side heat exchangers **6** are connected, a parallel multi-stage compression-type compression mechanism may be employed in which two or more multi-stage compression mechanisms are connected in parallel.

For example, as shown in FIG. **23**, the refrigerant circuit **510** in Modification 5 described above (refer to FIG. **20**) may be configured as a refrigerant circuit **610** that employs a compression mechanism **102** in which two-stage compression-type compression mechanisms **103**, **104** are connected in parallel, instead of the two-stage compression-type compression mechanism **2**.

In the present modification, the first compression mechanism **103** is configured by a compressor **29** for subjecting the refrigerant to two-stage compression through two compression elements **103***c*, **103***d*, and is connected to a first intake branch tube **103***a* which branches off from an intake header tube **102***a* of the compression mechanism **102**, and also to a first discharge branch tube **103***b* whose flow merges with a discharge header tube **102***b* of the compression mechanism **102**. In the present modification, the second compression mechanism **104** is configured by a compressor **30** for subjecting the refrigerant to two-stage compression through two compression elements **104***c*, **104***d*, and is connected to a second intake branch tube **104***a* which branches off from the intake header tube **102***a* of the compression mechanism **102**, and also to a second discharge branch tube **104***b* whose flow merges with the discharge header tube **102***b* of the compression mechanism **102**. Since the compressors **29**, **30** have the same configuration as the compressor **21** in the embodiment and modifications thereof described above, symbols indicating components other than the compression elements **103***c*, **103***d*, **104***c*, **104***d* are replaced with symbols beginning with **29** or **30**, and these components are not described. The compressor **29** is configured so that refrigerant is drawn from the first intake branch tube **103***a*, the refrigerant thus drawn in is compressed by the compression element **103***c* and then discharged to a first inlet-side intermediate branch tube **81** that constitutes the intermediate refrigerant tube **8**, the refrigerant discharged to the first inlet-side intermediate branch tube **81** is caused to be drawn into the compression element **103***d* by way of an intermediate header tube **82** and a first discharge-side intermediate branch tube **83** constituting the intermediate refrigerant tube **8**, and the refrigerant is further compressed and then discharged to the first discharge branch tube **103***b*. The compressor **30** is configured so that refrigerant is drawn in through the second intake branch tube **104***a*, the drawn-in refrigerant is compressed by the compression element **104***c* and then discharged to a second inlet-side intermediate branch tube **84** constituting the intermediate refrigerant tube **8**, the refrigerant discharged to the second inlet-side intermediate branch tube **84** is drawn into the compression element **104***d* via the intermediate header tube **82** and a second discharge-side intermediate branch tube **85** constituting the intermediate refrigerant tube **8**, and the refrigerant is further compressed and then discharged to the second discharge branch tube **104***b*. In the present modification, the intermediate refrigerant tube **8** is a refrigerant tube for sucking refrigerant discharged from the compression elements **103***c*, **104***c* connected to the first-stage sides of the compression elements **103***d*, **104***d* into the compression elements **103***d*, **104***d* connected to the second-stage sides of the compression elements **103***c*, **104***c*, and the intermediate refrigerant tube **8** primarily comprises the first inlet-side intermediate branch tube **81** connected to the discharge side of the first-stage compression element **103***c* of the first compression mechanism **103**, the second inlet-side intermediate branch tube **84** connected to the discharge side of the first-stage compression element **104***c* of the second compression mechanism **104**, the intermediate header tube **82** whose flow merges with both inlet-side intermediate branch tubes **81**, **84**, the first discharge-side intermediate branch tube **83** branching off from the intermediate header tube **82** and connected to the intake side of the second-stage compression element **103***d* of the first compression mechanism **103**, and the second discharge-side intermediate branch tube **85** branching off from the intermediate header tube **82** and connected to the intake side of the second-stage compression element **104***d* of the second compression mechanism **104**. The discharge header tube **102***b* is a refrigerant tube for feeding refrigerant discharged from the compression mechanism **102** to the switching mechanism **3**. A first oil separation mechanism **141** and a first non-return mechanism **142** are provided to the first discharge branch tube **103***b* connected to the discharge header tube **102***b*. A second oil separation mechanism **143** and a second non-return mechanism **144** are provided to the second discharge branch tube **104***b* connected to the discharge header tube **102***b*. The first oil separation mechanism **141** is a mechanism whereby refrigeration oil that accompanies the refrigerant discharged from the first compression mechanism **103** is separated from the refrigerant and returned to the intake side of the compression mechanism **102**. The first oil separation mechanism **141** mainly has a first oil separator **141***a* for separating from the refrigerant the refrigeration oil that accompanies the refrigerant discharged from the first compression mechanism **103**, and a first oil return tube **141***b* that is connected to the first oil separator **141***a* and that is used for returning the refrigeration oil separated from the refrigerant to the intake side of the compression mechanism **102**. The second oil separation mechanism **143** is a mechanism whereby refrigeration oil that accompanies the refrigerant discharged from the second compression mechanism **104** is separated from the refrigerant and returned to the intake side of the compression mechanism **102**. The second oil separation mechanism **143** mainly has a second oil separator **143***a* for separating from the refrigerant the refrigeration oil that accompanies the refrigerant discharged from the second compression mechanism **104**, and a second oil return tube **143***b* that is connected to the second oil separator **143***a* and that is used for returning the refrigeration oil separated from the refrigerant to the intake side of the compression mechanism **102**. In the present modification, the first oil return tube **141***b* is connected to the second intake branch tube **104***a*, and the second oil return tube **143***c* is connected to the first intake branch tube **103***a*. Accordingly, a greater amount of refrigeration oil returns to the compression mechanism **103**, **104** that has the lesser amount of refrigeration oil even when there is an imbalance between the amount of refrigeration oil that accompanies the refrigerant discharged from the first compression mechanism **103** and the amount of refrigeration oil that accompanies the refrigerant discharged from the second compression mechanism **104**, which is due to the imbalance in the amount of refrigeration oil retained in the first compression mechanism **103** and the amount of refrigeration oil retained in the second compression mechanism **104**. The imbalance between the amount of refrigeration oil retained in the first compression mechanism **103** and the amount of refrigeration oil retained in the second compression mechanism **104** is therefore resolved. In the present modification, the first intake branch tube **103***a* is configured so that the portion leading from the flow juncture with the second oil return tube **143***b* to the flow juncture with the intake header tube **102***a* slopes downward toward the flow juncture with the intake header tube **102***a*, while the second intake branch tube **104***a* is configured so that the portion leading from the flow juncture with the first oil return tube **141***b* to the flow juncture with the intake header tube **102***a* slopes downward toward the flow juncture with the intake header tube **102***a*. Therefore, even if either one of the compression mechanisms **103**, **104** is stopped, refrigeration oil being returned from the oil return tube corresponding to the operating compression mechanism to the intake branch tube corresponding to the stopped compression mechanism is returned to the intake header tube **102***a*, and there will be little likelihood of a shortage of oil supplied to the operating compression mechanism. The oil return tubes **141***b*, **143***b* are provided with depressurizing mechanisms **141***c*, **143***c* for depressurizing the refrigeration oil that flows through the oil return tubes **141***b*, **143***b*. The non-return mechanisms **142**, **144** are mechanisms for allowing refrigerant to flow from the discharge side of the compression mechanisms **103**, **104** to the switching mechanism **3**, and for shutting off the flow of refrigerant from the switching mechanism **3** to the discharge side of the compression mechanisms **103**, **104**.

Thus, in the present modification, the compression mechanism **102** is configured by connecting two compression mechanisms in parallel; namely, the first compression mechanism **103** having two compression elements **103***c*, **103***d* and configured so that refrigerant discharged from the first-stage compression element of these compression elements **103***c*, **103***d* is sequentially compressed by the second-stage compression element, and the second compression mechanism **104** having two compression elements **104***c*, **104***d* and configured so that refrigerant discharged from the first-stage compression element of these compression elements **104***c*, **104***d* is sequentially compressed by the second-stage compression element.

In the present modification, the intercooler **7** is provided to the intermediate header tube **82** constituting the intermediate refrigerant tube **8**, and the intercooler **7** is a heat exchanger for cooling the conjoined flow of the refrigerant discharged from the first-stage compression element **103***c* of the first compression mechanism **103** and the refrigerant discharged from the first-stage compression element **104***c* of the second compression mechanism **104**. Specifically, the intercooler **7** functions as a shared cooler for two compression mechanisms **103**, **104**. Accordingly, the circuit configuration is simplified around the compression mechanism **102** when the intercooler **7** is provided to the parallel-multistage-compression-type compression mechanism **102** in which a plurality of multistage-compression-type compression mechanisms **103**, **104** are connected in parallel.

The first inlet-side intermediate branch tube **81** constituting the intermediate refrigerant tube **8** is provided with a non-return mechanism **81***a* for allowing the flow of refrigerant from the discharge side of the first-stage compression element **103***c* of the first compression mechanism **103** toward the intermediate header tube **82** and for blocking the flow of refrigerant from the intermediate header tube **82** toward the discharge side of the first-stage compression element **103***c*, while the second inlet-side intermediate branch tube **84** constituting the intermediate refrigerant tube **8** is provided with a non-return mechanism **84***a* for allowing the flow of refrigerant from the discharge side of the first-stage compression element **104***c* of the second compression mechanism **104** toward the intermediate header tube **82** and for blocking the flow of refrigerant from the intermediate header tube **82** toward the discharge side of the first-stage compression element **104***c*. In the present modification, non-return valves are used as the non-return mechanisms **81***a*, **84***a*. Therefore, even if either one of the compression mechanisms **103**, **104** has stopped, there are no instances in which refrigerant discharged from the first-stage compression element of the operating compression mechanism passes through the intermediate refrigerant tube **8** and travels to the discharge side of the first-stage compression element of the stopped compression mechanism. Therefore, there are no instances in which refrigerant discharged from the first-stage compression element of the operating compression mechanism passes through the interior of the first-stage compression element of the stopped compression mechanism and exits out through the intake side of the compression mechanism **102**, which would cause the refrigeration oil of the stopped compression mechanism to flow out, and it is thus unlikely that there will be insufficient refrigeration oil for starting up the stopped compression mechanism. In the case that the compression mechanisms **103**, **104** are operated in order of priority (for example, in the case of a compression mechanism in which priority is given to operating the first compression mechanism **103**), the stopped compression mechanism described above will always be the second compression mechanism **104**, and therefore in this case only the non-return mechanism **84***a* corresponding to the second compression mechanism **104** need be provided.

In cases of a compression mechanism which prioritizes operating the first compression mechanism **103** as described above, since a shared intermediate refrigerant tube **8** is provided for both compression mechanisms **103**, **104**, the refrigerant discharged from the first-stage compression element **103***c* corresponding to the operating first compression mechanism **103** passes through the second discharge-side intermediate branch tube **85** of the intermediate refrigerant tube **8** and travels to the intake side of the second-stage compression element **104***d* of the stopped second compression mechanism **104**, whereby there is a danger that refrigerant discharged from the first-stage compression element **103***c* of the operating first compression mechanism **103** will pass through the interior of the second-stage compression element **104***d* of the stopped second compression mechanism **104** and exit out through the discharge side of the compression mechanism **102**, causing the refrigeration oil of the stopped second compression mechanism **104** to flow out, resulting in insufficient refrigeration oil for starting up the stopped second compression mechanism **104**. In view of this, an on/off valve **85***a* is provided to the second discharge-side intermediate branch tube **85** in the present modification, and when the second compression mechanism **104** has stopped, the flow of refrigerant through the second discharge-side intermediate branch tube **85** is blocked by the on/off valve **85***a*. The refrigerant discharged from the first-stage compression element **103***c* of the operating first compression mechanism **103** thereby no longer passes through the second discharge-side intermediate branch tube **85** of the intermediate refrigerant tube **8** and travels to the intake side of the second-stage compression element **104***d* of the stopped second compression mechanism **104**; therefore, there are no longer any instances in which the refrigerant discharged from the first-stage compression element **103***c* of the operating first compression mechanism **103** passes through the interior of the second-stage compression element **104***d* of the stopped second compression mechanism **104** and exits out through the discharge side of the compression mechanism **102** which causes the refrigeration oil of the stopped second compression mechanism **104** to flow out, and it is thereby even more unlikely that there will be insufficient refrigeration oil for starting up the stopped second compression mechanism **104**. An electromagnetic valve is used as the on/off valve **85***a* in the present modification.

In the case of a compression mechanism which prioritizes operating the first compression mechanism **103**, the second compression mechanism **104** is started up in continuation from the starting up of the first compression mechanism **103**, but at this time, since a shared intermediate refrigerant tube **8** is provided for both compression mechanisms **103**, **104**, the starting up takes place from a state in which the pressure in the discharge side of the first-stage compression element **103***e* of the second compression mechanism **104** and the pressure in the intake side of the second-stage compression element **103***d* are greater than the pressure in the intake side of the first-stage compression element **103***c* and the pressure in the discharge side of the second-stage compression element **103***d*, and it is difficult to start up the second compression mechanism **104** in a stable manner. In view of this, in the present modification, there is provided a startup bypass tube **86** for connecting the discharge side of the first-stage compression element **104***c* of the second compression mechanism **104** and the intake side of the second-stage compression element **104***d*, and an on/off valve **86***a* is provided to this startup bypass tube **86**. In cases in which the second compression mechanism **104** has stopped, the flow of refrigerant through the startup bypass tube **86** is blocked by the on/off valve **86***a* and the flow of refrigerant through the second discharge-side intermediate branch tube **85** is blocked by the on/off valve **85***a*. When the second compression mechanism **104** is started up, a state in which refrigerant is allowed to flow through the startup bypass tube **86** can be restored via the on/off valve **86***a*, whereby the refrigerant discharged from the first-stage compression element **104***c* of the second compression mechanism **104** is drawn into the second-stage compression element **104***d* via the startup bypass tube **86** without being mixed with the refrigerant discharged from the first-stage compression element **103***c* of the first compression mechanism **103**, a state of allowing refrigerant to flow through the second discharge-side intermediate branch tube **85** can be restored via the on/off valve **85***a* at point in time when the operating state of the compression mechanism **102** has been stabilized (e.g., a point in time when the intake pressure, discharge pressure, and intermediate pressure of the compression mechanism **102** have been stabilized), the flow of refrigerant through the startup bypass tube **86** can be blocked by the on/off valve **86***a*, and operation can transition to the normal air-cooling operation. In the present modification, one end of the startup bypass tube **86** is connected between the on/off valve **85***a* of the second discharge-side intermediate branch tube **85** and the intake side of the second-stage compression element **104***d* of the second compression mechanism **104**, while the other end is connected between the discharge side of the first-stage compression element **104***c* of the second compression mechanism **104** and the non-return mechanism **84***a* of the second inlet-side intermediate branch tube **84**, and when the second compression mechanism **104** is started up, the startup bypass tube **86** can be kept in a state of being substantially unaffected by the intermediate pressure portion of the first compression mechanism **103**. An electromagnetic valve is used as the on/off valve **86***a* in the present modification.

The actions of the air-conditioning apparatus **1** of the present modification during the air-cooling operation and the air-warming operation, and the like are essentially the same as the actions in the above-described Modification 5 (FIGS. **20** through **22**, **18**, and **19** and the relevant descriptions), except that the points modified by the circuit configuration surrounding the compression mechanism **102** are somewhat more complex due to the compression mechanism **102** being provided instead of the compression mechanism **2**, for which reason the actions are not described herein.

The same operational effects as those of Modification 5 described above can also be achieved with the configuration of the present modification.

In the present modification, switching between air-cooling operation and air-cooling start control, i.e., switching between the refrigerant non-return state and the refrigerant return state, is accomplished by the on/off states of the on/off valves **11**, **12**, **92***a*. However, an intercooler switching valve **93** may also be provided which is capable of switching between a refrigerant non-return state and a refrigerant return state, instead of the on/off valves **11**, **12**, **92***a*, as in Modification 1 described above.

(9) Other Embodiments

Embodiments of the present invention and modifications thereof are described above with reference to the drawings, but the specific configuration is not limited to these embodiments or their modifications, and can be changed within a range that does not deviate from the scope of the invention.

For example, in the above-described embodiment and modifications thereof, the present invention may be applied to a so-called chiller-type air-conditioning apparatus in which water or brine is used as a heating source or cooling source for conducting heat exchange with the refrigerant flowing through the usage-side heat exchanger **6**, and a secondary heat exchanger is provided for conducting heat exchange between indoor air and the water or brine that has undergone heat exchange in the usage-side heat exchanger **6**.

The present invention can also be applied to other types of refrigeration apparatuses besides the above-described chiller-type air-conditioning apparatus, as long as the apparatus performs a multistage compression refrigeration cycle by using a refrigerant that operates in a supercritical range as its refrigerant.

The refrigerant that operates in a supercritical range is not limited to carbon dioxide; ethylene, ethane, nitric oxide, and other gases may also be used.

Industrial Applicability

The present invention makes it possible to prevent liquid compression in the second-stage compression element, and to enhance the reliability of the compression mechanism in a refrigeration apparatus which performs a multi-stage compression refrigeration cycle.

What is claimed is:

1. A refrigeration apparatus, comprising

a compression mechanism having a plurality of compression elements, refrigerant discharged from a first-stage compression element of the plurality of compression elements being sequentially compressed by a second-stage compression element of the plurality of compression elements;

a heat source-side heat exchanger;

a usage-side heat exchanger;

an intermediate refrigerant tube drawing refrigerant discharged from the first-stage compression element into the second-stage compression element;

an intercooler disposed along the intermediate refrigerant tube and dividing the intermediate refrigerant tube into an inlet side portion connected to an outlet of the first-stage compression element and an inlet side of the intercooler, and an outlet side portion connected to an intake side of the second-stage compression element and an outlet side of the intercooler,

the intercooler cooling the refrigerant discharged from the first-stage compression element into the inlet side portion and supplying cooled refrigerant into the outlet side portion to be drawn into the second-stage compression element;

an intercooler bypass tube connected to the intermediate refrigerant tube and bypassing the intercooler;

an intake return tube branching from the inlet side portion of the intermediate refrigerant tube on the inlet side of the intercooler to an intake side of the first stage compression element of the compression mechanism to fluidly communicate refrigerant in the inlet side portion prior to passing through the intercooler to the intake side of the first-stage compression element when the refrigerant discharged from the first-stage compression element is drawn into the second-stage compression element through the intercooler bypass tube; and

a switching mechanism switching between

a cooling operation state in which refrigerant is circulated in sequence through the compression mechanism, the heat source-side heat exchanger, and the usage-side heat exchanger, and

a heating operation state in which refrigerant is circulated in sequence through the compression mechanism, the usage-side heat exchanger, and the heat source-side heat exchanger,

the intercooler bypass tube connecting the refrigerant discharged from the first-stage compression element into the second-stage compression element at the start of operation in which the switching mechanism is in the cooling operation state, and

the intake return tube connecting the intercooler and the intake side of the compression mechanism at the start of operation in which the switching mechanism is in the cooling operation state.

2. The refrigeration apparatus according to claim **1**, further comprising

an intercooler switching valve switching between

a refrigerant non-return state in which the refrigerant discharged from the first-stage compression element is drawn into the second-stage compression element via the intercooler, and the intercooler and the intake side of the compression mechanism are not connected via the intake return tube, and

a refrigerant return state in which the refrigerant discharged from the first-stage compression element is drawn into the second-stage compression element through the intercooler bypass tube, and the intercooler and the intake side of the compression mechanism are connected via the intake return tube.

3. The refrigeration apparatus according to claim **1**, wherein

the intercooler bypass tube connecting the refrigerant discharged from the first-stage compression element into the second-stage compression element when the switching mechanism is in the heating operation state, and

the intake return tube connecting the intercooler and the intake side of the compression mechanism when the switching mechanism is in the heating operation state.

4. The refrigeration apparatus according to claim **3**, further comprising

an intercooler switching valve switching between

a refrigerant non-return state in which the refrigerant discharged from the first-stage compression element is drawn into the second-stage compression element via the intercooler, and the intercooler and the intake side of the compression mechanism are not connected via the intake return tube, and

a refrigerant return state in which the refrigerant discharged from the first-stage compression element is drawn into the second-stage compression element through the intercooler bypass tube, and the intercooler and the intake side of the compression mechanism are connected via the intake return tube.

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